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Exploring the relationship between New Product Development, Concurrent Engineering, and Project Management to improve product development

Adán López Miranda

The Bartlett School of Graduate Studies

University College London

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I, Adán López Miranda, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

To my lovely wife Ruth Angélica for her patience, love and comprehension

To my four kids Angélica, Adán, Andrés, and Adriana

In memoriam to my father and mother

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Vitae

Adan Lopez Miranda, BSc in Mechanical Engineering and MSc in Manufacturing Systems at Tecnologico de Monterrey, Mexico. Assistant Professor and Consultant at the Centre for Innovation in Design and Technology at Tecnologico de Monterrey, Mexico. Lecturer in Project Management in the Industrial Engineering Department. He has been working in the project management field for some twenty years, working in engineering, quality systems, and R & D projects. Project Management Professional® by the Project Management Institute in the USA since 1999. Speaker and Consultant on project management in Mexico and overseas, including Panama, and Colombia. Adan Lopez Miranda's main research interest is in Project Management, New Product Development, Concurrent Engineering and Collaborative working. He has published several papers in proceedings and journals on these topics, four of them emerging from this research.

ABSTRACT

This thesis describes the results of research aimed at exploring the relationship between three different practices to improve product development: Concurrent Engineering (CE), New Product Development (NPD), and Project Management (PM). The literature on each approach is abundant, yet studies explaining their inter-relationship are scanty and contradictory. Therefore, the main contribution of this thesis is explanation and clarification of contradictory theories and perspectives.

In exploring this relationship four cases studies were developed in companies that were applying these practices. Principles of the grounded theory and qualitative research were applied to gather and analyse data.

The results suggest that CE, NPD, and PM are relatively different in practice and purpose and therefore they can be complementary to each other. However, because of a lack of clearer definitions and boundaries they are sometimes considered competing approaches, as has been observed both in the literature and in practice.

CE, NPD, and PM were difficult to perceive as a sub-component one of the other as has been suggested in the literature. Rather, inter-linked process models seemed to better explain how the inter-relationship was understood and applied. The data gathered from the case studies suggest cause-effect relationships that may guide practitioners to implement or improve their product development practices.

The investigation explores the essence, purpose and the knowledge generation process of CE, NPD and PM. It is suggested that NPD has a higher level of maturity than CE and NPD. This suggestion and the corresponding discussion is thought to be a contribution of current philosophical debates on the subject areas thereby nurturing the research agenda.

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Research stimuli

This research was spawned by an invitation from a university colleague to participate in a concurrent engineering (CE) workshop to talk about project management (PM). Intrigued by the invitation, I asked my colleague (a true expert in CE) what the relationship between CE and PM was and his answer was simple and confident: "PM is a tool of CE".

I had been working as project manager, lecturer and consultant on project management for many years. According to my expertise, CE was only a particular PM strategy aimed at compressing the project schedule by overlapping activities. Thus, the simple suggestion that PM was part of CE disturbed my well structured (I believed) framework of theory and praxis.

Therefore, I began a brief review of books and journals in search for an explanation about the relationship between CE and PM. However, although the literature on each topic was abundant, few sources discussed the relationship, and even worse, the authors did not agree. Later, a third approach appeared on the scene: New Product Development (NPD), an approach aimed at managing the development of new products (coincidentally the same purported purpose of CE and PM). To complicate matters, the NPD literature also presented contrasting perspectives about the relationship between NPD, CE, and PM. For instance, some authors subsumed CE and PM into an overall NPD process. Interestingly, there were very few cross-references between the CE, NPD, and PM literature.

Hence, encouraged by the 'search for the truth' (and no less by my wounded pride), I started a research endeavour aimed at clarifying 'who was who' and how academics and practitioners could benefit from a clearer and multidisciplinary explanation.

...I believe that I have realised this goal.

Chapter 1 Introduction

"Despite the risks involved with developing and launching new innovations, companies love them because they drive profits, growth, and shareholder value" (Chakravorti, 2004: 60). In order to minimise the risks and to increase the benefits of innovation, practitioners engage in the application of "best practices" for developing new products which are grounded in different knowledge fields such as marketing, organisation theory, engineering design and operations management (Krishnan and Ulrich, 2001). From these knowledge fields, three approaches aim at improving product development: Concurrent Engineering (CE), New Product Development (NPD), and Project Management (PM).

CE has been described by many as an integrated process for reducing the product development cycle time (Bowonder et al, 2004). It has received increasing attention since the 1980s when companies reported "impressive" gains not only in reducing the project lead-time but also the costs and an improvement in product quality (Winner et al, 1988). Nowadays, the applications of CE span a variety of economic sectors, including: aerospace, automotive, process science and technology, transportation, construction, medical services, electronics, and education (Sharma, 2004). Haque (2003) points out that CE is gradually becoming the norm for developing and introducing new products to the market place.

NPD has been receiving attention by the scholars since the 1960s (Barclay, 1992), that is, before CE came to the scene. Since then many benefits of applying NPD have been reported, amongst others, increased revenues, productivity and operational efficiency (McGrath, 1997). NPD received special attention when studies proved Japanese companies to be superior in quality, costs, and product development lead-time when compared with western companies (Womack et al, 1990; Clark and Fujimoto, 1992). Cooper (2001) affirmed that the NPD process, including the management of the product portfolio, a business-gated process and the integration between marketing and operations, is nowadays the key to gain market share. Recently, Perks (2005) showed that attention to pacing and synchronisation of partner activities can add value to the development process thereby increasing the benefits of applying NPD.

PM is an approach that has been applied since the last century in a great variety of projects, including new product development projects (Morris, 1977). The lore of PM is closely linked to systems engineering up to the point that they appear to be synonymous (Cleeland and King, 1983; NASA, 2002). According to Cleland and Ireland (2000) the application of PM increases competitiveness, profits, employee morale and so on. Rosenau (1993) affirmed that developing new products is a project-orientated activity with specific time-related tasks and objectives. This temporary nature of the new product development process and of the project organisation conveys the application of PM methods (Tatikonda and Roshental, 2000). Recently, Engwall and Svensson (2004) illustrated the way organizations deal with unanticipated problems in product development projects by the ad hoc launching of temporary organizations called cheetah teams. These teams are applying the most modern approach to PM as they deal with unanticipated and urgent problems.

The three approaches have been purported as *the approach* for managing the development of new products bringing about both financial and technical benefits. There can be others but around these three considerable research has been developed and professional communities of academics and practitioners have been formed around the globe (e.g., the Concurrent Engineering Conference e-Group[1], the Product Development Management Association[2], and the Project Management Institute[3]).

Although literature on these three approaches is abundant, both at practitioner and at academic level, there seems to be a dearth of treatises explaining how they can be related. Additionally, the studies dealing with the subject seem to be biased, consciously or unconsciously, towards one or the other approach apparently depending on authors' own background. As a result some contradictory or confusing issues do not happen to be clearly explained. It is for instance uncertain to what extent PM can be applied in developing new products. To some authors (e.g. Blackburn, 1991) PM is too mechanistic to be applicable. To some others the development of new products is the organizational

[1] www.ceconf.com

[2] www.pdma.org

[3] www.pmi.org

process of managing a project (Rosenau, 1993, Tatikonda and Rosenthal, 2002). It is unclear which approach is a component of the other. For instance, a CE classification system around which different tools and techniques are grouped includes PM as a particular technique (SCPD, 2004). On the other hand, however, a PM classification system included NPD and CE as PM application and process areas respectively (Kloppenborg and Oppfer, 2002). Their very essence is sometimes at the stake and a number of authors classify one or the other as a discipline (Morris, 1997), paradigm (Gerwin and Barrowman, 2002), technique (Mileham et al, 2004), or even fad (Fleming and Koppleman, 1997). The nature of their knowledge has not been compared as has been done with other subject areas like sociology, political sciences or organisation theory (Lodhal and Gordon, 1972; Pfeffer, 198).

Product development is fundamentally a multidisciplinary process (Olson et al, 2001) and therefore practitioners need to know how to combine more efficiently (resource optimisation) and effectively (targeting business goals) CE, NPD, and PM. It is therefore useful to achieve a better understanding on their differences, similarities and constituent dimensions. Such an understanding is also essential for developing and testing theories relating CE, NPD, and PM.

This thesis presents the results of multidisciplinary research aimed at improving the management of product development by investigating the relationship between CE, NPD, and PM. The main research goal was stated as follows:

To develop an exploratory study aimed at understanding the relationship between Concurrent Engineering, New Product Development, and Project Management.

Three general questions were expected to be answered[4]:

(a) Do CE, NPD, and PM practices emphasize essentially the same aspects (practice and purpose), or are they distinctly different?

(b) Are CE, NPD, and PM competing or complementary practices?

(c) Is one a component or a precursor of the other?

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[4] The nature of the questions was drawn from Narasimhan et al's (2006) study on the relationship between Lean Manufacturing and Agile Manufacturing.

The exploratory study was based on the multiple-case study methodology (Eisenhardt, 1989; Meredith, 1988; Yin 1993). Practitioners at different hierarchical levels dealing with product development were interviewed in four companies (cases). A case study protocol was used to prepare and conduct the in-depth interviews (Yin, 1993). Documents in the form of manuals, process maps, and instructions, as well as observations, complemented the empirical data from which the resulting explanations regarding the relationship were induced. The unit of analysis was the product development process as the research sought to investigate cross-sectional how these processes had been implemented, operated and improved from three different perspectives (CE, NPD, and PM).

The methods used to analyse the data drew on existing descriptions of how to generate theory from qualitative data, particularly writings by Strauss and Corbin (1988), Milles and Huberman (1994) and Yin (1993, 1994). These methods helped to cope with the staggering volume of data, to interplay with data and theory and to shape the concepts with more explanatory power, based on a creative lap (Mintzberg, 1979).

Organizational structures (charts) were explored in the field and explained in this thesis to set the context in which products were developed. However, the organizational dimension of product development, that is, how the companies are organised from the point of view of structure, hierarchy and functional interfaces was not addressed basically because of limitations imposed by time and resources.

Likewise, the co-relation between performance and the application of these three approaches was not investigated basically because of the exploratory nature of this research. However, it is believed that the emerging concepts of this research lend themselves to facilitate an investigation on this issue.

The results of this research are exploratory and therefore they require confirmatory analysis. However, it is believed that the findings contribute to knowledge as they present explanations of otherwise confusing, not refined or contradictory theories. The discussion of the results vis-à-vis the extant literature raised interesting questions about the intrinsic nature and goals of each approach.

This thesis is structured as follows from the second chapter onwards:

- Chapter 2 describes briefly Concurrent Engineering, New Product Development, and Project Management. The chapter then delves into the literature about the relationship between the three different approaches. From this review, the main theoretical issues and questions are formulated.

- Chapter 3 substantiates the selection of the case study research methodology including an explanation of the process to analyse the empirical data gathered in the field.

- Chapter 4 describes the four case studies. The primary intention is to gain an understanding of every case in order to develop a better cross-case analysis. Additionally, the data unveils answers to some of the research issues.

- Chapter 5 presents the cross-case analysis. Concepts, relationships and conceptual frameworks to understand the relationship between PM, NPD and CE emerge in this chapter.

- Chapter 6 answers the research questions and discusses the main theoretical issues by comparing the empirical results with the extant literature. The implications are then put forward. Finally the main limitations in conducting the research are commented alongside an evaluation of the emergent theory.

- Chapter 7 presents the conclusions, the main contributions to knowledge, and the topics for further research.

- Appendices contain the preliminary conceptual frameworks, the access letter, the case study protocol, and views of the software used to analyse data.

Chapter 2 Literature review

This chapter presents the results of the literature review. It is divided in two sections, the first section describes briefly CE, NPD, and PM and the second section dwells upon the relationship between CE, NPD, and PM. The second section highlights the gaps, confusions and contradictions that spawned the main theoretical issues of this thesis.

To describe each approach in the same way, the following framework is used:

- Origins and definitions
- Methods, techniques and classification systems
- Purported benefits
- Implementation methods
- Main research topics

2.1 Concurrent Engineering

2.1.1 Origins and definitions

Engineering products in a concurrent way is not a new concept. Pioneers of the automobile industry like Henry Ford and Ransom Olds practised, to a certain extent, "the philosophy of what we now call CE" (Jo et al, 1991: 35). Hence, concepts like "multifunctional teams", "integrating design and manufacturing functions", "customer focus", and "time to market" have been in the literature since the 1920s (Smith, 1997). According to Hobday et al (2005) the application of multidisciplinary teams working concurrently at the outset to develop weapon systems in a more efficient and effective way was a fundamental principle of systems engineering during the Cold War era. These principles were later applied in the automobile and electronics industries and "terms such as concurrent engineering are now common place" (Hobday et al, 2005: 1121).

However, a considerable stream of research and the integration of academic and professional communities around Concurrent Engineering probably began in the 1980s. At that time the DoD (Department of Defence) tasked the Institute for Defence Analyses

(IDA) "to assess claims of improved product quality at lower costs and shortened product development time through the use of CE" (Winner et al , 1988: v). The resulting report (Winner et al, 1998) is now a milestone in the history of CE which is defined as follows:

> CE is the systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements. (Winner et al., 1988: v).

Another well-accepted definition of CE was proposed by Cleetus:

> CE is a systematic approach to integrated product development, that emphasizes response to customer expectations and embodies team values of cooperation, trust, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life cycle perspectives, synchronized by comparatively brief exchanges to produce consensus. (Cleetus, 1992: 3)

Simultaneous Engineering (SE) is a concept linked to CE. Winner et al (1988: 11) found that both terms had been used to describe similar approaches. Lettice et al (1999) gathered 18 definitions of CE and SE and listed all of them as CE definitions. The following definition illustrates the close similarity:

> Simultaneous Engineering is an organizational strategy. The idea is to shorten the time of product design by simultaneous planning of product and production. Retailers and buyers of the means of production are working together during the product design phase. So the demands on the means of production are specified at the very earliest moment. The results are shorter innovative times and lower costs. (Eversheim, 1990: 8).

Willaert et al (1998) affirmed that CE should also cover suppliers and information technology. The authors then coined the term Collaborative Engineering and dubbed it as CE II (Concurrent Engineering II). Accordingly:

> Collaborative Engineering is a systematic approach to control lifecycle cost, product quality, and time to market during product development by concurrently developing products and their related processes in response to customer expectations, where decision making ensures input and evaluation by all lifecycle functions and disciplines, including suppliers, and information technology is applied to support information exchange where necessary" (Willaert et al 1998: 98).

2.1.2 Methods, techniques and classification systems

An extensive number of tools and techniques have been grouped around CE. Winner et al (1998) developed case studies in 10 different companies and classified the different methods, tools and techniques as shown in Table 2-1.

Table 2-1. CE classification of methods, tools and techniques by Winner et al (partial view) (1988)

Engineering process initiatives	**Formal methods**
Multifunction teams.	QFD
Design documentation management.	Design for assembly
Tracking the (customer) requirements.	Fault tree analysis
Process design.	FMEA
Computer and other technology support	Group technology
Information management and communication	Simulation (Soft Mock-up)
Integrating technologies	Process measurement and control
Production technologies	On line process control

Many other methods, tools and techniques have been incorporated since this classification was published (Table 2-2 shows some illustrative examples). The Institute for Defence Analysis, for instance, lists over sixty CE tools and techniques (Evans, 1993). Likewise, many models, frameworks, classification systems or taxonomies have been developed to group the different methods, tools and techniques, some of which will be presented next for illustrative purposes.

Table 2-2. Illustrative examples of CE methods, tools and techniques

Method, tool or technique	References
Statistical quality control	Veness, P. J. et al 1996
Web-based collaborative systems	Huang et al. 1999
Advanced Product Quality Plan (APQP)	Al-Ashaab, A., 1999
Process Modelling	Haque, B., Pawar, K.S., 2001
Knowledge engineering and management	Ceconf 2001
Virtual environment/Virtual enterprise	
Virtual Prototyping	

Prasad (1996) developed a model of CE represented by two "wheels" (Figure 2-1). In this case, the concept of CE is extended to product development, including manufacturing, and considerations of life cycle management.

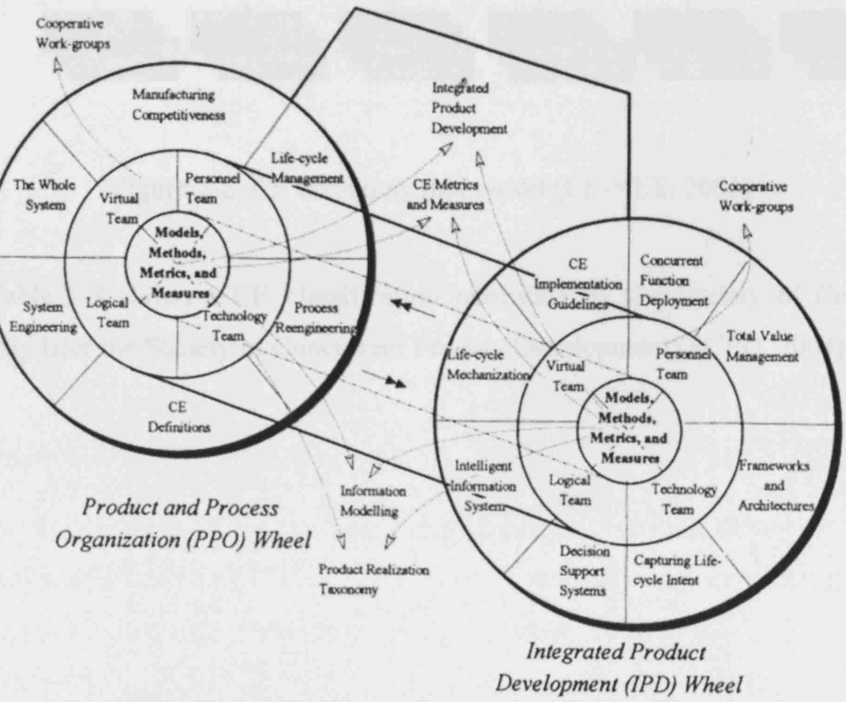


Figure 2-1. A synchronized set of CE wheels (Prasad, 1996: xv)

The University of Twente developed a taxonomy of CE concepts "which structures the complex domain with sufficient level of detail" (Wognum et al, 2001: 3). The taxonomy is shown in Figure 2-2 at the first level only (it contains three hierarchical sub-levels) to illustrate the massive knowledge areas that have been grouped around CE.

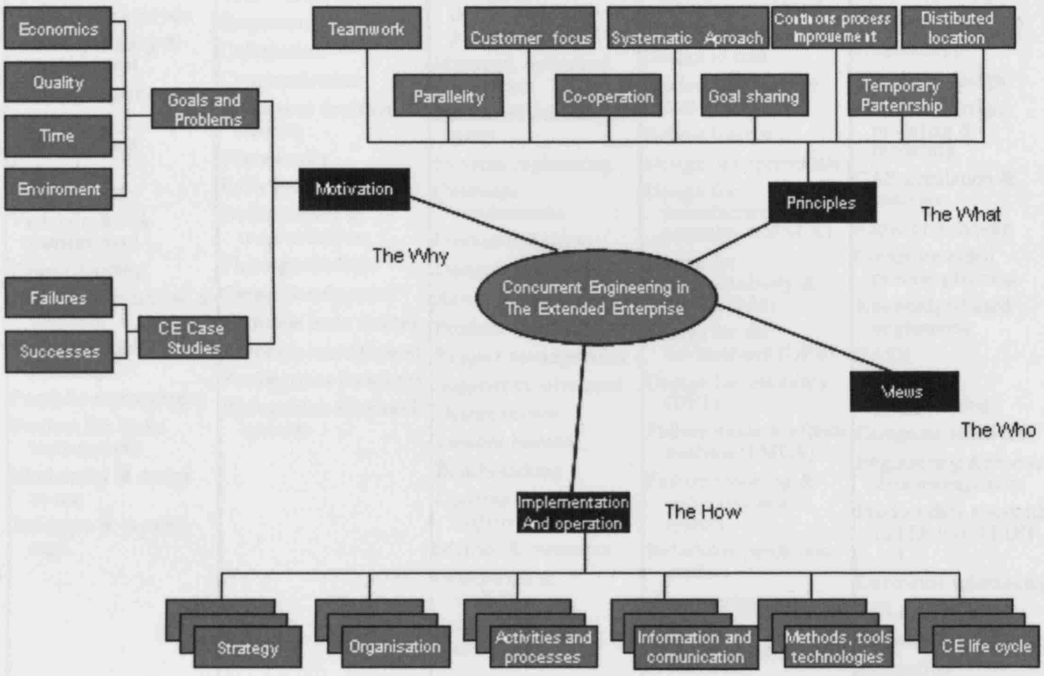


Figure 2-2. CE taxonomy main level (CE-NET: 2001)

Finally, Table 2-3 shows a CE classification published by the Society of Concurrent Engineering, later the Society of Concurrent Product Development (SCPD, 2004).

[12] www.pdma.org

Table 2-3. Example of a CE classification system (SCPD, 2004) (Bold text added by the researcher)

STATEGY	PEOPLE	PROCESS	TOOLS	TECHNOLOGY
Business & product strategy Market research Competitive analysis Product planning & management R&D management Innovation management Technology deployment Variation & risk management Project funding Project prioritization & selection Process funding & planning Portfolio management Product life cycle management Modularity & design re-use Resource & capacity mgt.	Leadership Cross-functional teams Teamwork Empowerment Collocation Communication Consensus decision making Team leader Early involvement Defined roles & responsibilities Flat organizations Career development Common team charter Resource management Performance measures Recognition & reward systems	Reengineering Concurrency Structured, documented processes Managed, optimized processes Phases, milestones, & gates Systems engineering Customer requirements Product definition Design guidelines Reverse engineering Product specifications **Project management** Supplier involvement Design review Lessons learned Benchmarking Continuous improvement Metrics & measures Groupware & workflow Collaborative computing	Quality function deployment (QFD) Standard parts libraries, preferred parts lists Design to cost Product & life cycle cost models Robust Design Design of experiments Design for manufacture & assembly (DFM/A) Design for maintainability & serviceability Design for the environment (DFE) Design for testability (DFT) Failure mode & effects analysis (FMEA) Failure reporting & corrective action system Reliability prediction models Group technology (GT) Value engineering	Digital product model Design repositories Solids modeling Electronic mock-up Frameworks Top-down design Industrial Design modeling & rendering CAE simulation & analysis Rapid prototyping Computer-aided process planning Knowledge-based engineering CASE CAM/NC programming Computer-aided test Engineering &product data management Product data standards (STEP,IGES,EDIF, ...) Geometric tolerancing EDI & CAL Decision support Integration

As illustrated, so many practices, techniques, and tools have been classified under the name Concurrent Engineering (e.g., Market Research, Statistical Quality Control, Quality Function Deployment, and even PM) that it has become unclear whether CE still has, or indeed ever had, an identifiable conceptual core.

2.1.3 Purported Benefits

Many benefits of applying CE have been reported (see for instance, Winner et al 1988; Abdalla, 1999; and Bowonder et al 2004) and can be summarised as developing products in less time and cost and with better quality. Hartley (1992), for instance, list the following benefits:

- Improving the quality of designs, which results in dramatic reductions of engineering change orders (greater than 50 percent) in early production.

- Product development cycle-time reduced by as much as 40 to 60 percent through the concurrent, rather than sequential, design of product and processes.
- Manufacturing cost reduced by as much as 30 to 40 percent by having multifunction teams to integrate product and process designs.
- Scrap and rework reduced by as much as 75 percent through product and process design optimisation.

2.1.4 Implementation methods

Pawar et al (2002) affirmed that few CE implementation processes had been published. To address this shortage, the authors proposed an implementation framework that can be tailored to the technique that is to be implemented (Figure 2-3). The authors commented that "the framework could be used as part of a guided tour for (say) the project manager or simply as an overview of what implementation of CE typically involves" (Pawar et al, 2002: 85).

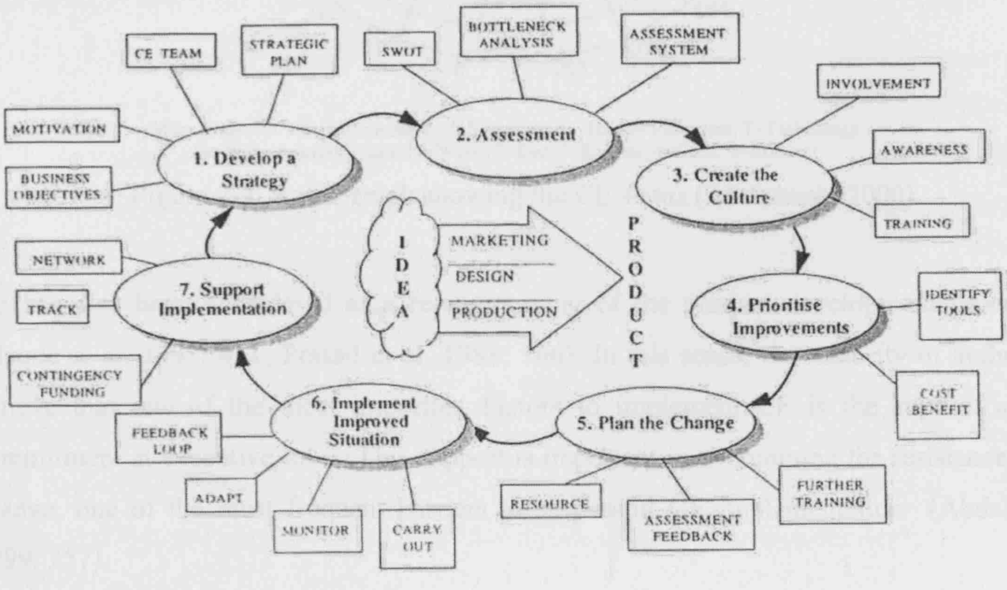
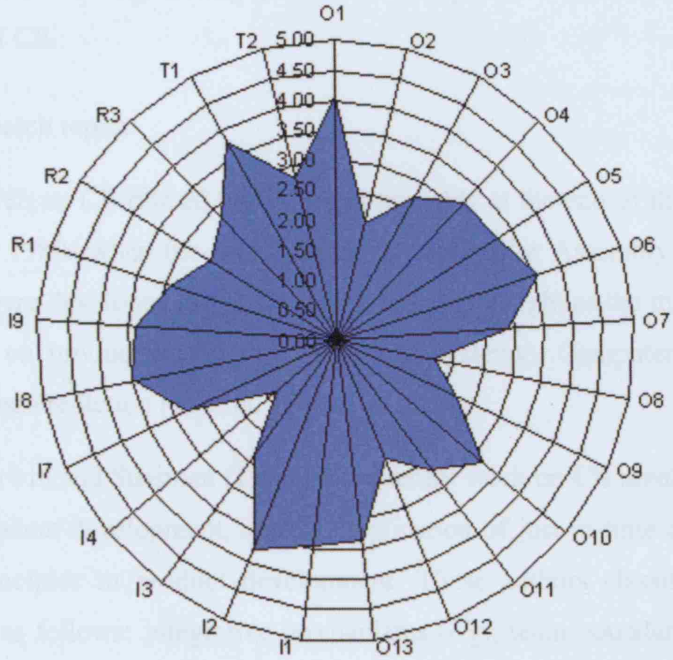


Figure 2-3. Implementation framework for CE (Pawar et al, 2002)

Many authors have proposed assessment tools to evaluate the actual status of the organisation in relation to CE practices (Veness et al, 1996; Van Landegem, 2000; Al-

Ashab and Valdepeña, 2000; Ainscough et al, 2003). Through the application of these assessment tools, the organisations identify the main opportunities, as well as the route for achieving CE. Al Ashaab and Valdepeña (2000), for instance, apply a questionnaire of 25 questions divided into four groups and the results are presented in a radar-type graph (Figure 2-4).



Main groups: O – Organizational; I – Information; R – Human Resources; T- Technology
Performance measurement: 1=Worst; 2=Bad; 3=Regular; 4=Good; 5=Excelent

Figure 2-4. Radar graph showing the CE status (Al-Ashaab, 2000)

CE has also been considered as a re-engineering of the product development process (Haque et al, 1997: 451; Prasad et al, 1988: 166). In this sense, the majority of authors believe that one of the most important factors to implement CE is the support and commitment at executive level. This support is important in overcoming the resistance to change, one of the most frequent barriers to successful CE implementation (Abdalla, 1999: 257).

To cope with the resistance to change, Swink (1998) describes four managerial factors that increase the probability of success:

- Elevate the project since CE initiatives contradict conventional ways of working, therefore, it is vital to view the project as a special undertaking.

- Elucidate goals, which stimulates interaction between the right people, at the right time and to the right extent.
- Eliminate barriers to integration in order to break out cumbersome bureaucracy and traditional functional domains of power.
- Develop concurrent engineering processes and promote a shared vision of the importance of CE.

2.1.5 Main research topics

Pioneering research on CE-related topics began probably at the end of the 1970s and the beginning of the 1980s when the main studies on Design for Assembly and Design for Manufacturing were developed (Jo et al, 1991). In the late eighties the main CE research streams focused on product modelers (CAD/CAM systems), Computer Aided Process Planning, and Cost Prediction (Jo et al, 1990).

According to Gerwin and Sussman (1996), more recent work on CE involves information processing in product development, and the application of just-in-time and total quality management principles to product development. These authors classified special CE research studies as follows: integrative mechanisms (e.g., team boundaries, co-location, performance evaluation), group process (e.g., two-way communication, overlapping tasks, set-based design), codification/computerization (e.g., common language, design heuristics, interface technology), and task conditions (newness, complexity, early/late product life cycle) (Gerwin and Sussman, 1996: 119).

An analysis of the papers submitted during the 10 years of ISPE/CEconf conference (Wognum et al, 2003) revealed that CE research has been addressing integrative mechanisms, parallelism, and teamwork. Recently, another category of research papers were submitted including conflict resolution, information management and access, simulation tools and process improvement methods, supply chain management, and early supplier involvement.

A similar analysis was done regarding the 10 years of the Concurrent Enterprising Conference (Lettice, et al, 2004). The topics included CE methods and tools, virtual organizations, project management, product data management, e-Work, e-Business, and collaborative design. The authors concluded that the topic focus had changed from CE and CE tools to Knowledge Management.

2.2 New Product Development

2.2.1 Origins and definitions

Managing innovation concerns the development of specific new products where the interest lies in the structures and processes by which individuals create products (Brown and Eisenhardt. 1995). This section presents a brief description of this approach, which is also called New Product Development (NPD).

NPD started to be recognised as a subject area at the end of the 1960s and the start of the 1970s when several studies were launched aimed at finding product development success factors (Barclay, 1992). One of the most famous research projects was SAPPHO, which systematically compared successful innovations with unsuccessful innovations (Barclay, 1992). Griffin (1997) reports on the pioneering studies developed by Booz Allen Hamilton in 1968, where it was revealed that almost one third of all product development projects commercialised by firms were failures.

NPD has been named variously as Product Development, New Product Introduction, Integrated Product Development, Integrated New Product Development, Concurrent Product Development and so on. Table 2-4 shows some definitions.

Table 2-4. Concepts and definitions of NPD

New Product Process: a formal blueprint, roadmap, template or thought process for driving a new product project from the idea stage through to market launch and beyond. (Cooper, 1994: 3)
We define product development as the transformation of market opportunity and a set of assumptions about product technology into product availability for sale. (Krishnan and Ulrich, 2001)
New Product Development: The overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product. Also frequently referred to just as *product development* (PDMA, 2003a).

2.2.2 Methods, techniques and classification systems

Relatively few sources (compared with CE) were found listing NPD methods, tools, techniques or taxonomies. Rather, NPD authors focused more on strategies, organisational structures, and processes management issues. Table 2-5 presents an example of NPD tools as classified by two authors. Note that Project Management and other CE related tools like QFD and Design for Manufacturability are included.

Table 2-5. Methods, tools and techniques to develop new products (bold added by the researcher)

Author	Methods, tools, and techniques
Wheelwright and Clark, 1992	- The design-build-test cycle - **QFD** - **Design for Manufacturability** - **Project Management** and Execution - Computer Based Design Systems (like CAD/CAM)
Mc Grath, 1996.	- QFD - Design for Assembly and Manufacturability. - User-Oriented Design - Design and Execution Tools - **Project Management** and Execution Tools

One of the few NPD taxonomies identified was a classification developed by the Product Development Management Association (PDMA[2]). This taxonomy, shown in Table 2-6, was issued as a common body of knowledge and helps, for instance, to assess product development professionals who wish to obtain a professional certification issued by the PDMA (PDMA, 2003b).

It should be noted that the NPD classification issued by the PDMA explicitly includes PM and CE typical techniques like prototyping, reverse engineering, and QFD. As will be seen later, PM taxonomies also include NPD and CE methods, tools and techniques, thereby making it necessary to clarify the relationship.

Table 2-6. NPD tools and techniques (PDMA, 2003b) (Bold text added by the researcher)

Strategy	Teams, people and organisational issues	New product process
Mission, vision and values SWOT analysis Strategic scanning Strategic assessment Entry strategy PIC (Product Innovation Charter) Platforms	Team leadership and purpose Team process, tools and training New product process roles and responsibilities (top management, sponsors, champions, facilitators) New product process organizational structures: projectization and external Types of team structures Culture and environment (external) Interface management - cross-functional Selection of team members	Development stages: Opportunity identification and evaluation Concept generation Concept evaluation Development Launch Stage gates Process owner/facilitator Fuzzy front end Decision making Concept screening Ideation Capturing employee ideas
Portfolio management	**Tools and metrics**	**Market research**
What is portfolio management? Why is portfolio management needed? Portfolio management basic tools Selection criteria	Forecasting (and financial analysis) Metrics **Quality functional deployment (QFD)** **Project management** **Risk management** Benchmarking **Prototyping** **Reverse engineering**	Competitive intelligence Lead user research Voice of the customer Customer visits Concept testing Focus groups Secondary market research Product use testing Market testing Surveys

2.2.3 Purported Benefits

The purported benefits of NPD are also similar to CE's, as can be seen from the following list (McGrath, 1996):

- Increased revenues. Increased product life-cycle revenue, increased market penetration as a result of being first to market, success in time-sensitive markets, and more successful products.

- Improved product development productivity. Shorter development cycle times, less development waste, better resource utilisation, and better ability to attract and retain technical talent.

- Operational efficiencies. Design for manufacturability, serviceability and so on, higher quality products, lower engineering change order costs, and improved predictability of launch.

2.2.4 Implementation methods

There are several methods to implement an NPD approach. Cooper (2001) and many others strive for the creation of a product portfolio and the development of a stage gate process. Barclay et al (2000) developed an assessment tool (similar to CE tools) to find and prioritize opportunity areas around NPD, then recommending the creation of internal groups in the company to address these opportunities.

Probably one of the most frequently cited methods is the PACE approach (McGrath, 1996), Product And Cycle time Excellence. It is a methodology based on four "project management" elements: phase review process, the core team approach, structured development process, and development tools and techniques (Figure 2-5). Additionally it considers three "cross-project management" elements: the process of product strategy, technology management, and pipeline (Figure 2-6).

McGrath's methodology explains in detail the development of core teams, product committees and the technology management process to incorporate R&D technologies into products.

Although the main components of the methodology are called "project management" by the author, the term has little connection with the concept of project management, which will be explained in the next section.

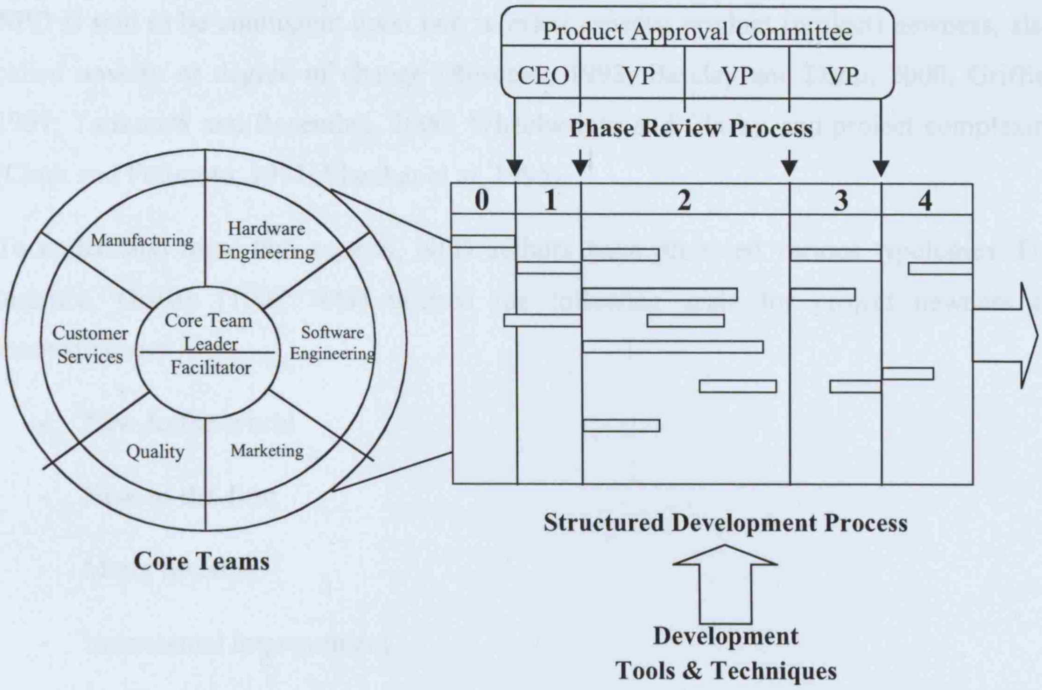


Figure 2-5. The four "project management" elements of PACE (McGrath, 1996)

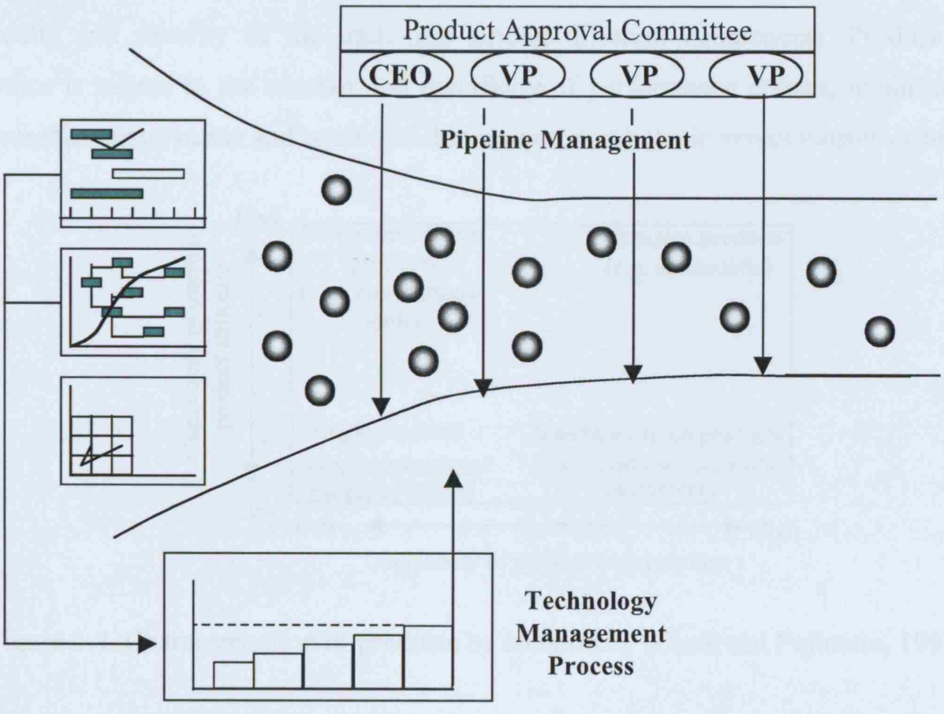


Figure 2-6. The three "cross-project management" elements of PACE (McGrath, 1996)

NPD is said to be contingent upon two relevant aspects: product (project) newness, also called novelty or degree of change (Rosenau, 1993; Barclay and Dann, 2000; Griffin, 1997; Tatikonda and Rosenthal, 2000; Wheelwright and Clark); and project complexity (Clark and Fujimoto, 1991; Shenhar et al, 1995).

To understand these two aspects, NPD authors have proposed various typologies. For instance, Griffin (1997: 449) utilised the following scale for project newness or innovativeness:

- New-to-the-world
- New-to-the-firm
- Major revision
- Incremental improvement

Another illustrative example is Clark and Fujimoto's typology of product complexity (Figure 2-7). According to this typology, "product internal structure" refers to the number of distinct components, production steps, number of interfaces, and technological difficulty and severity of the trade-offs among different components. Product user-interface is related to the number and specificity of performance criteria, importance of measurable versus subtle and equivocal dimensions, and holistic versus narrow criteria.

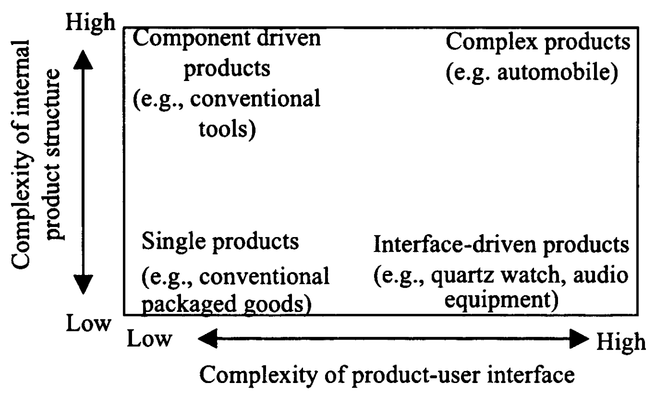


Figure 2-7. Characterisation of products by complexity (Clark and Fujimoto, 1991: 11)

2.2.5 Main research topics

Much research has been developed around NPD critical success factors. According to Barclay (1992), the main factors associated with success found in 1977 were:

- Good communication and effective collaboration
- Innovation as a corporate wide task
- Efficient development work
- Careful planning and the use of management techniques
- The quality of management, personnel policy and management style
- Marketing and user needs
- After sales service and user education
- Key individuals in greater positions of authority

A different stream of research focuses on analysing product development as a process. One of the leading researchers in this field has been Cooper who in 1983 published a new product development process consisting of seven stages and a corresponding number of review gates (Cooper, 1983). According to this author, the new process was a second-generation process to develop products, the first being the Phased Review Process. The main differences according to Cooper were that the first generation process was very engineering driven and the second generation process was more cross-functional, integrating manufacturing and marketing, and having a stronger market orientation (Cooper, 1994). Later, Cooper introduced the third-generation process consisting of a reduction to five-steps and recommending the use of "flexible" gates instead of rigid go no-go decision gates. These flexible gates would allow practitioners to start downstream stages before finishing upstream ones thereby reducing time to market (Cooper, 1994). A symbolic comparison of Cooper's 2nd and 3rd generation of flexible stage gate process is shown in Figure 2-8. Other authors have also investigated ways to achieve the right balance between setting gates to control the process and overlapping stages to gain time to market (Rosenau, 1996; Eisenhard and Tabrizi, 1995; Terwiesch and Loch, 1999; and Lautier, 1996).

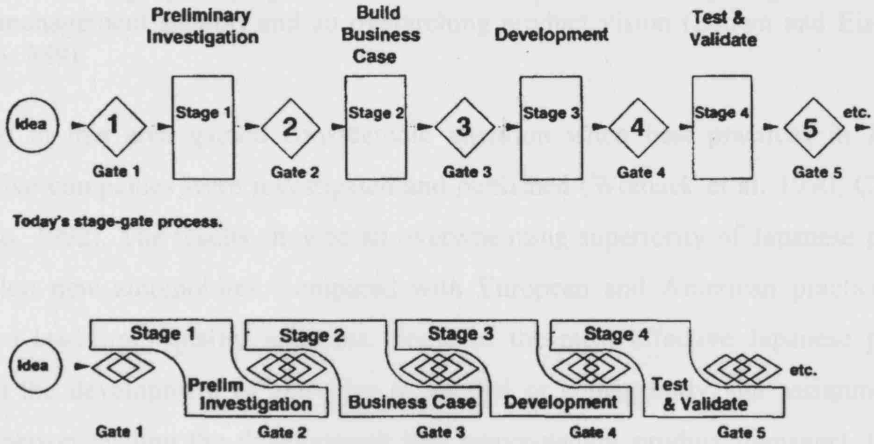


Figure 2-8. Symbolic representation of the stage-gate process (2nd and 3rd generation) and flexible gates (Cooper, 1994)

The portfolio of new products is another subject largely studied by NPD researchers and applied by practitioners (Cooper et al 1999, Wheelwright and Clark, 1992). It basically consists of creating a set of strategic criteria to select, prioritize and screen projects so that companies have the capacity to develop only those new products that are aligned with business goals. According to NPD authors, the portfolio of new products is the first stage in developing new products and the second is the NPD process (Cooper, 2001).

Brown and Eisenhardt (1995) reviewed the NPD literature and found that the subject has been studied from three different perspectives: as a rational plan; as a communication web; and as disciplined problem-solving. What follows is the description of these three perspectives according to the authors:

> Product development as rational plan. This rational perspective emphasizes that successful product development is the result of (a) careful planning of a superior product for an attractive market and (b) the execution of that plan by a competent and well-coordinated cross-functional team that operates with (c) the blessing of senior management (Brown and Eisenhardt, 1995: 348).

> Product development as communication web…the underlying premise is that communication among project team members and with outsiders stimulates the performance of development teams (Brown and Eisenhardt, 1995: 353-4).

> Product development as disciplined problem solving…in this case, successful product development is seen as a balancing act between relatively autonomous

> problem solving by the project team and the discipline of a heavyweight leader, strong top management support and an overarching product vision (Brown and Eisenhardt, 1995: 359).

Research in this area gained considerable attention when best practices in Japanese automotive companies were investigated and published (Womack et al. 1990, Clark and Fujimoto, 1992). The results showed an overwhelming superiority of Japanese practices to develop new automobiles, compared with European and American practices, with regard to lead-time, quality and cost. Some of the most effective Japanese practices included the development of activities in parallel or concurrently, the assignment of a unique person leading the development (the heavy-weight product manager), the team problem solving approach, and the horizontal structure of suppliers (Clark and Fujimoto, 1992).

Probably because of the Japanese influence, authors proposed a new title for NPD, namely Integrated (or Concurrent) Product Development (IPD) (Khury and Plevyak, 1994; Pawar et al 1999; Gerwing and Barrowman, 2002; Büyüközkan et al, 2004). In fact, to Gerwin and Barrowman (2002), IPD became "*the* paradigm for NPD". The two following definitions reveal this kind of symbiosis between NPD and CE:

> Integrated Product Development is a philosophy that systematically employs a teaming of functional disciplines to integrate and concurrently apply all necessary processes to produce an effective and efficient product that satisfies customer's needs. (Khuri and Plevyak, 1994).

> Integrated Product Development is a managerial approach for improving new product development performance (e.g. development time), which occurs in part through the overlap (partially or completely parallel execution) and the interaction (exchange of information) of certain activities in NPD process. (Gerwin and Barrowman, 2002).

Literature on NPD has been so vast that, according to Krishnan and Ulrich (2001), it has been necessary to organize it into a few "competing paradigms" stemming from different academic communities: Marketing, Organizations, Engineering Design, and Operations Management (the authors position Project Management under this last perspective).

2.3 Project Management

2.3.1 Origins and definitions

Managing projects is a task carried out practically since the beginning of civilisation. How otherwise could extraordinary endeavours like the Seven Wonders of the Ancient World have been carried out? As a professional discipline, however, PM might have started "in the 1930s with the US Air Corps' and Exxon's project engineering co-ordinating function" (Morris, 1997: 213). At the end of the 1960s PM began to be recognised as a knowledge field *per se* when many papers addressing scheduling and risk analysis tools like PERT (Program Evaluation and Review Technique) and CPM (Critical Path Method) were published (Shenhar and Dvir, 2004). Systems engineering is a discipline that has inextricably been linked to PM (Cleeland and King, 1983; Morris, 1997; NASA, 2002). Both were applied in huge military/aerospace projects sponsored by the DOD (Department of Defence) and the NASA in the USA, like the historic Apollo Project, which culminated in the first man on the moon. CE has also been related to systems engineering (Winner et al, 1988; Hobday et al, 2005) which suggests a close overlap amongst CE and PM.

Both practitioners and scholars have attempted to define *project management* and *project* since the 1950s (Atkinson, 1999). Other definitions appeared later in Project Management Bodies of Knowledge (PMBOK) and standards issued by professional societies. Table 2-7 and Table 2-8 show exemplars.

2.3.2 Two different perspectives of PM

The literature reviewed reveals that nowadays PM is regarded from two perspectives which in essence differ in its conceptual breath or scope. One perspective considers that PM involves basically three stages: planning, execution and closure. The first stage (planning) starts with project authorisation and the last stage (closure) ends up with an administrative closure and the resulting product or service which is handed over to production or consumption. From this perspective what happens before and after is treated only as a context and not precisely as a PM domain. Presumably the key project success factors seem to be the quality or performance of the product, the time, and the costs of the project (Kerzner, 1998: 5; Meredith and Mantel, 2003: 4). According to Morris (2001) a clear example of this purview is the Project Management Body of

Knowledge (PMBOK) issued by the Project Management Institute (PMI) in the USA. This perspective will be referred hereinafter as the "Pm execution perspective".

Table 2-7. Concepts and definitions of *project management*

Project Management is the application of the systems approach to the management of technologically complex tasks or projects whose objectives are explicitly stated in terms of time, cost, and performance parameters. (Gouse and Stickney, 1988: 869)
Project Management is the application of knowledge, skills, tools, and techniques to project activities in order to meet project requirements. (PMBOK-PMI, 2000: 6)
Project Management is the whole leading activities, organisation, techniques, and resources for the development of a project. (DIN 69901, 1998 in Motzel and Pannenbäcker[4], 1988: 12)
Planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance. (APMP, 2000: 36)
Project Management is the process of planning, organizing, directing, and monitoring all aspects of project´s realisation (CRMP, 1999).

Table 2-8. Concepts and definitions of *project*

A project is a temporary endeavour undertaken to create a unique product or service. (PMBOK-PMI, 2000: 4)
A project is a unique process, consisting of a set of co-ordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including the constraint of time, cost and performance. (ISO 10006, 1997: 1).
An endeavour in which human, material, and financial resources are organized in a novel way, to undertake a unique scope of work, of given specification, within constraints of cost and time, so as to achieve beneficial change defined by quantitative and qualitative objectives. (Turner, 1993)

The other PM perspective considers a broader scope including project and programs evaluation and selection (which happens before project authorisation), project external factors, product technology, and links between projects and business goals. This PM broader perspective was probably first proposed through the *Management of Projects* framework (Morris and Hough, 1987; Morris, 1997) and according to Morris (2001) is represented amongst others by the PMBOK of the Association for Project Managers (APM) in UK (PMBOK-APM, 2000). This perspective will be called herein after the "PM broader perspective"

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[4] Researcher's translation from German to English

[6] Business Process Reengineering

The management of projects (MP) concept emerged as a result of empirical research conducted to analyse success and failure factors in eight "major" projects, e.g., the Channel Tunnel and the supersonic Concorde (Morris and Hough, 1987). In this study, the authors concluded that project success (or failure) involves issues lying outside the project execution scope, like business strategies, project screening and politics. In addition, the authors suggested that project success factors are not only related to quality, time and costs, but also to other factors like the business goals, the management of the technology, commercial aspects, ecological impacts and so on. Later, Morris analysed the success and failure of many important projects from practically the 2nd World War up to the 80s, confirming the need for a broader PM perspective to increase the possibilities of project success (Morris, 1997). Since the development of the MP proposal, researchers have embraced this broader perspective (Winch, 2000; Morris and Pinto, 2004). Shenhar and Dvir (2004: 5) make a clear distinction between a PM execution and a PM broader perspective: "Operationally managed projects focus on getting the job done, while strategically managed projects focus on achieving business results". Other concepts that seems to embrace the broader PM broader perspective are *Management by Projects* and *Program Management.*

Management by Projects (MbyP) is a strategy for project-orientated companies (Gareis, 1989; Gareis, 1991). Unlike companies developing a few 'major' projects for external customers, in the project-orientated companies, many internal and external, as well as small and big projects, are developed simultaneously. The essential difference between MbyP and the PM broader perspective might be that the former claims for a movement from the management of a single project to the management of a "network of projects" integrated into the company by an explicit business strategy and a corporate culture (Gareis, 1991).

Program management (PgM) has recently become mainstreamed as a PM broader perspective, whereas in the past it did not happen to be substantially different from the PM execution perspective and they were even sometimes considered as synonymous (Cleland and King, 1983: 70; Archibald, 1992: 24). Recent opinions about the concept and scope of PgM differ as will be briefly presented next.

Turner (1992) and the Department of Defence in the USA (DODI 5000.2, 2002) seem to conceptualise a program as a group of projects managed in a co-ordinated way. The

PMBOK-PMI (2000: 10) added that programs may be composed of projects and ongoing operations. NASA defines programs as 'major' activities which consist of one or more projects, the latter having a more definite beginning and end (NASA, 2002). Additionally, NASA describes the strategic and tactical difference between a program manager and a project manager as follows:

> The Program Manager is responsible for ensuring that program goals address the Enterprise Strategic Plan and that projects, technology, infrastructure, or services supported by the program address the program goals" (NASA, 2002: 11)

> The Project Manager focuses on the day-to-day execution of the project by industrial contractors, universities, NASA personnel, and others (NASA, 2002: 12)

According to Thiry (2004: 245) "PgM needs to reflect the concepts and rhetoric of strategic long-term management, rather than the tactical short-term view of project management". Authors and institutions have proposed PgM as an effective approach to bring about the strategic change in organisations (Becker, 1999; Reiss, 2004; OGC, 2004). For instance, Levene and Braganza (1996) stated that BPR[6] projects should be formulated and managed as programs of related change projects, affirming that it is difficult to apply "conventional" project management in these projects.

2.3.3 Methods, techniques and classification systems

PM professional organisations have developed different taxonomies to classify and relate methods, tools, and techniques. For example, The PMI in the USA classifies them within nine knowledge areas (Figure 2-9). As illustrated, the great number of tools and techniques reveals that nowadays, PM comprises more than simply scheduling techniques like PERT, the Critical Path Method or the Gantt chart, as it did in the past. Nonetheless, this classification system is thought to represent the Pm execution perspective (Morris, 2002).

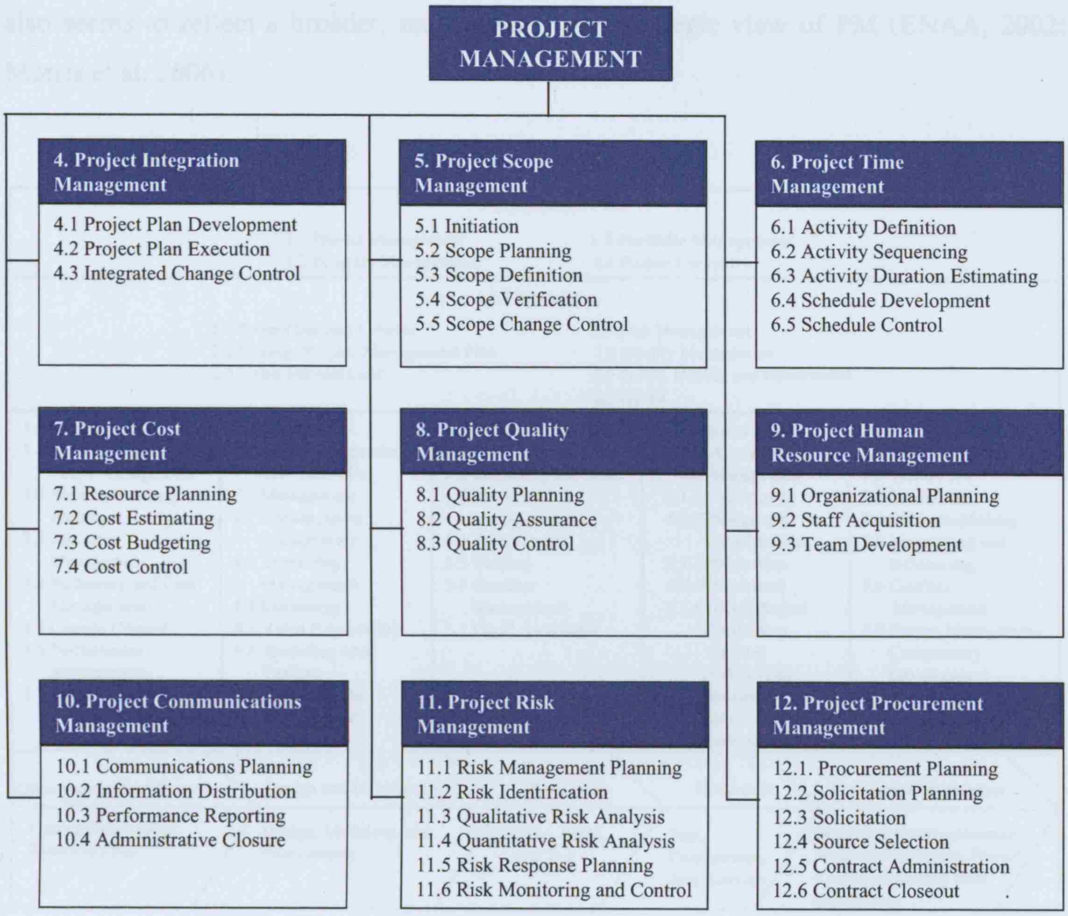

Figure 2-9. Overview of the nine PM knowledge areas (PMBOK-PMI, 2000)

The PMBOK-APM (2000) developed a PM taxonomy which more clearly reflects the PM broader perspective (Figure 2-10) by including issues that are clearly outside the Pm execution perspective like portfolio management, program management, and post-project evaluation. This broader PM classification system was developed based on a survey applied to around 450 project managers from 117 companies in the UK [Morris, 2001] which might give evidence that the broader PM perspective has been empirically corroborated. However, since the survey and the design of the questionnaire was led by Morris (one of the main proponents of the MP perspective) and applied to current APM members (already familiarized with their BOK), the results might have been biased.

It should be noted that the P2M BOK integrated by the Japanese ENAA (Engineering Advancement Association of Japan) and JPMF (Japanese Project Management Forum) also seems to reflect a broader, more holistic and strategic view of PM (ENAA, 2002; Morris et al, 2006).

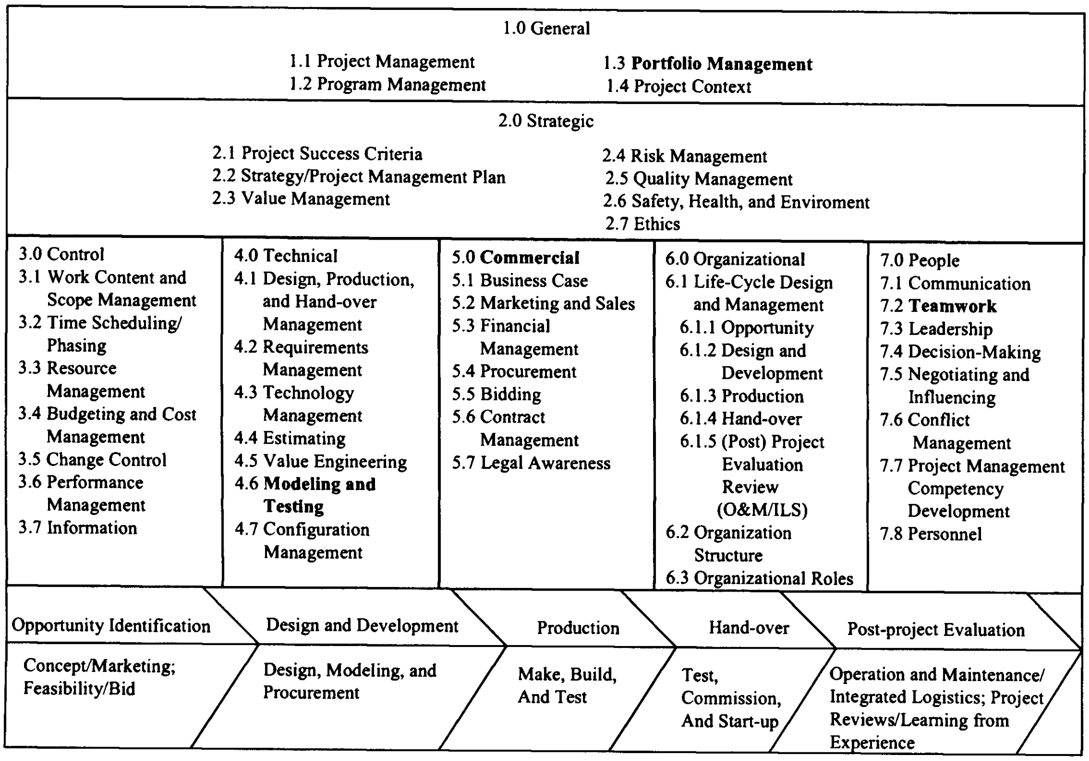

Figure 2-10. Classification of PM components according to APM (PMBOK-APM, 2000) (text added by the researcher)

The PMBOK-APM (2000) taxonomy (Figure 2-10) shows several issues that have been included in NPD and CE taxonomies, for instance, teamwork, commercial aspects, portfolio management, and technical aspects like modelling and testing. The PMBOK-PMI (2000) taxonomy (Figure 2-9) also includes some issues interfacing with CE and NPD taxonomies but to a lesser degree, like teamwork which is treated within the broader 9th knowledge area Project and Human Resource Management.

2.3.4 Purported Benefits

Unlike CE and NPD, literary sources quantifying the benefits of PM were difficult to find. Authors seem to take for granted that PM practices will have a positive impact on business goals, but little research has been done to quantify the benefits of PM vis-â-vis investments or costs (Morris, 2000; Thomas et al, 2002). The following is a list of benefits extracted from one of these few sources (Cleland and Ireland, 2000):

- Improved productivity by providing the most direct path to the solution of the problem.
- Improved profits by reducing wasted time and energy in the wrong solutions.
- Improved employee morale through greater job satisfaction.
- Improving competitive position within industry by bringing faster results to situations.
- Improved project process and workflow definitions.
- Improved capability and maturity in business solutions.
- More success and fewer failures through dedicated focus on work.
- Better decision making on continuation/termination of work efforts.
- Improved reward system for senior managers, project leaders, and project team members.
- Smoother integration of project results into the organisation.

It is clear that the benefits of the three approaches coincide. Thus, from a practical point of view, managers could reasonably question the need for investing in more than one approach.

2.3.5 Implementation methods

From the experiences with military and aerospace projects fundamental and systemic PM principles emerged: phasing the project; breaking it down; and considering the parts and the whole to control it. Moreover, the project life cycle is still, in practice, the fundamental principle on which to implement and apply PM (Morris, 2002: 85; Lunding and Söderholm, 1999: 19). The key managerial concept of the project life cycle is that "it reflects different management requirements at its various stages" (King and Cleland, 1988: 195). Derived from this principle, there should be a careful treatment of the interfaces between the stages (Thamhaim and Willemon, 1975; Adams and Barndt, 1988;

Archibald, 1992; Morris, 1998). An example of project life cycle is shown in Figure 2-11. The graphic illustrates how two managerial "needs" integration and flexibility are contingent upon the project stage. (Stahl and Dunne, 1984)

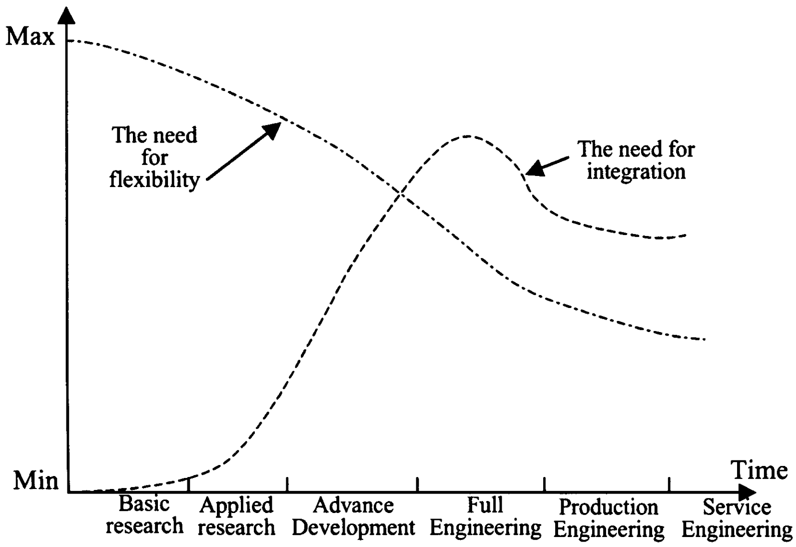

Figure 2-11. An example of project life cycle (adapted from Stahl and Dunne, 1984)

Companies apply PM by designing process-based methodologies according to their projects life cycle. Other companies prefer to adopt proven and free-of-access PM methodologies and tailor them to suit their particular needs. An example of such methodologies is PRINCE 2 which is defined as "a process-based approach for project management providing an easily tailored and scaleable method for the management of all types of projects" (OGC, 2003). The process model of PRINCE 2 is shown in Figure 2-12.

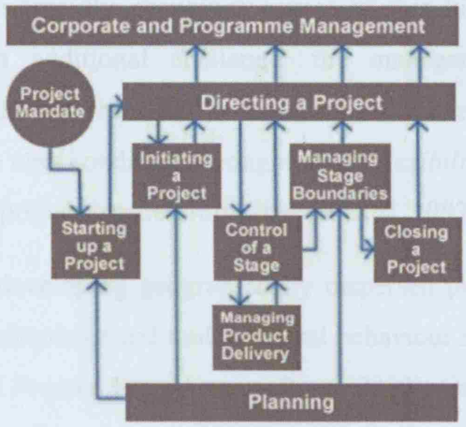

Figure 2-12. PRINCE 2 process model (OGC, 2003)

2.3.6 Main research topics

During the 1960s PM research focus was on scheduling and optimisation techniques (Shenhar and Dvir, 2004). Techniques like PERT and CPM were refined and others, like GERT and VERT, were created to simulate stochastic and cyclical networks. Likewise, resource allocation and levelling heuristics were developed to cope with the problem of limited resources in projects (Morris, 1997). Teamwork and integration became later (1970s) important research challenges because matrix structures started to be the most common form of organising PM (Laufer et al, 1997).

The next decade (1980s) witnessed the expansion of PM into industries other than military, aerospace and civil and construction. The application of PM in Information Technology/Systems (IT/IS) and New Product Development (NPD) projects was particularly significant (Morris, 1997). IT/IS projects challenged PM best practices because of the dynamic (rapidly changing) nature of this kind of project. The NPD projects represented an additional challenge: the management of projects in an environment in which the priorities and resources were shared with the production of existing products. These new conditions brought about *flexibility* as a new concept to be considered in managing projects successfully (Laufer et al. 1997).

Recently, the need for developing geographically dispersed projects challenged project teams to apply virtual technology and multi-cultural behaviour skills, giving birth to what has been dubbed *Virtual Project Management* (Pinto, 2002). On a different research line, a group of researchers confirmed the contingency theory (Laurence and Lorsch, 1967) in PM by sustaining that "one size does not fit all" (Engwall, 2003, Shenhar and Dvir, 2004, Lycett et al, 2004).

PM researchers started to question the most traditional PM fundamentals: the uniqueness and the temporality of the projects (Maylor et al, 2006). The uniqueness of a project, in the sense of "one-off" has for a long time been a fundamental tenet within the PM community. Nevertheless, Lundin and Söderholm (1998: 14) argued that some tasks having repetitive features should still be called projects, like building a house. Engwall (2003) analysed the PM approach applied to one successful and one unsuccessful project. Among other conclusions, this author affirmed that the study "calls into question the popular notion of projects as unique and solid units with distinctive demarcations to their organizational environment" (Engwall, 2003: 803).

The temporary aspect of the project is a key issue that seems to remain as the basis for PM. It is unequivocally linked to the project life cycle concept in which a project starts (is born), is developed (grows) and ends (dies). "The one single thing which distinguishes projects from non-projects is that all projects, no matter how complex or trivial, go through a common life cycle development sequence" (Morris, 2002: 5). Lundin and Söderholm (1998) have built upon this characteristic to propose a theory of temporary organisations. Nevertheless, some voices started to question this PM fundamental, particularly Söderlund who argues:

> The project life cycle has also, for obvious reasons, been the foundation for illuminating and capturing the inherent dynamics of project organizations, for instance in terms of pre-study and conclusion phases. This is however, merely one way of looking at the behaviour of project organizations. The work by Gersick has convincingly shown that the project life cycle is not a good description of how real

> projects evolve (reference is given). Hence, a number of questions might be raised whether the project life cycle is used normatively and if it is an adequate and appropriate description of reality or not. (Söderlund, 2004: 188)

The use of the project life cycle as the guiding model to implement PM methodologies in organisations has also been criticised as a new form of "re-bureaucratisation" (Hodgson, 2004) or a model by which "discourse technologies can redesign work processes, turning them into norms, rules and prescriptions, representing established consensual praxis" (Raisanen and Linde, 2004: 118). Williams (2005) also criticizes the prescriptive nature of Project Management claiming for the need of proposing new Project Management styles contingent upon project types.

Discussions about the proper scope of PM still go on (Pinto, 2000; Morris, 2001; Morris et al, 2006), and topics like program management (the broader concept), the link between business and project goals, and project portfolio management have received special attention.

Portfolio management "is concerned with groupings of projects along the interrelatedness of their management requirements" (Blomquist and Müller 2004: 2). Literature on portfolio management was found to address three distinct perspectives (Blomquist and Müller 2004: 3):

- Portfolio definitions and associated project selection techniques;
- Planning and management of project portfolios;
- Competencies for portfolio management.

Morris (2004) studied the link between corporate strategy, portfolio, programs and projects while Archer and Ghasemzadeh (2004) proposed an agenda for further research including the management of outsourced and high-tech risk portfolios, as well as collaborative commerce where cross-organizational knowledge sharing is one of the main barriers. Interestingly, most PM authors agree that portfolio management is a topic that has been studied in depth under NPD (as has been described in the corresponding NPD section), whereby emerges another interface between NPD and PM.

2.4 Summary

A brief description of CE, NPD, and PM has been presented to introduce the knowledge areas under research. At their origins, they appeared to be clearly differentiated, PM addressing project's scheduling techniques and the application of systems engineering (1950s), CE targeting methods to speed up product and process design (1980s), and NPD focusing on success factors in industrial innovations (1960s). However, they have been growing and evolving in such a way that they have invaded their respective spheres of action. For instance, it has been shown that the PM classification system of the APM BOK lists techniques typically included in CE classification systems and that CE classification systems include PM as one of it constituents.

The benefits of applying these three different approaches do not happen to differ greatly and can be summarised in the development of projects, new products, or designs faster, cheaper, and better and with the corresponding value added for the stakeholders.

The implementation methods seem to differ slightly. Given the myriad techniques, tools and methods applied in CE, a diagnostic is first recommended by researchers. From the results, an implementation process is launched aimed at introducing the most appropriate method. It is said that CE is to some extent "revolutionary", therefore implementers recommend being prepared for an organisational culture change. Both, NPD and PM seem to follow a similar route: a process or project life cycle is designed in order to set the stages and the review points along the development. The difference happens to be in the emphasis. Whereas NPD specifically addresses business and commercial aspects (product portfolio and product introduction to customers), Pm (execution perspective) addresses the development, from project start to project closure. This difference is now blurred since the PM broader perspective considers the alignment of projects to business goals through portfolio and program management.

The main research topics also show a certain degree of interference, e.g., teams, organizational structures, simultaneous development and so on, however there are notable differences. NPD research interest has been on the development of products that satisfy business needs, an interest that has recently started to be shared by the PM community. The CE community and the NPD community (to a lesser degree) have in particular researched the application of tools and techniques to address and satisfy customer needs. This last point has notably been missed in the PM research agenda.

The goal of the previous section has been to provide a brief description of what CE, NPD, and PM are, as well as their most salient similarities and differences. The following sections reviews in detail a number of differences similarities and contradictions, from which the main theoretical issues of this thesis emerge.

2.5 Theoretical Framework

2.5.1 Is CE an all-encompassing term?

Understanding the meaning of CE was one of the first tasks of this inquiry. Unfortunately, there are so many definitions and the basic concepts are so loosely used in the literature that CE appears to be a *catch-all* word.

The term was coined at the end of the 80s and since then, many definitions and concepts explaining what CE is (and what it is not) have appeared (see some samples in Table 2-9). Lettice et al (1999), for instance, gathered 18 different CE definitions.

Table 2-9. Concepts and definitions of CE

CE is the systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements. (Winner et al., 1988: v).
CE is a systematic approach to integrated product development, that emphasizes response to customer expectations and embodies team values of cooperation, trust, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life cycle perspectives, synchronized by comparatively brief exchanges to produce consensus. (Cleetus, 1992: 3)
CE is a design and engineering environment in which computer-aided design technology is used to assess and improve the quality of a product, not only during the active design phase but through its entire life cycle. (Ellis, 1992).
A synergy of multi-disciplinary teams incorporating different aspects of the product life cycle into the final product. (Rohatynsky, 1996).
Concurrent engineering is more an overall strategy than a unified methodology. (Veness et al 1996: 141)
CE is a design philosophy that focuses on integrating and managing a design process to shorten the development cycle of the product or process. (Skalak et al, 1997: 305).
CE, where all the up and downstream functions are brought into the design stage and work together throughout the product life cycle. (Kara et al, 1999: 269).
CE is not a simple undertaking, in fact it entails a multitude of approaches, methodologies and techniques. (Pawar, et al 2002: 91).

Cleetus, the author of one of the most frequently cited CE definitions, affirmed that "the term Concurrent Engineering (CE) has been loosely used to mean a host of different things. The development of the subject is retarded by such loose usage" (Cleetus, 1992: 1). Later, Gerwin and Susman (1996: 118) commented that "there is no-well accepted definition of CE". Despite these critics, authors formulated more definitions arguably because current definitions "do not address the drivers of CE" (Willaert et al, 1998: 98).

Wognum et al (2003) found that many terms had been used to identify CE in the last 10 years, like Simultaneous Engineering, Concurrent Product Development, Integrated Product Development, Communication-Colaboration-Coordination (CCC), Agile Manufacturing, and Collaborative Engineering. Likewise, the concept of CE has been closely related to systems engineering (Winner et al, 1988: 11; Hobday et al, 2005: 1121) and systems thinking (Bowonder et al, 2004: 203-204).

So many methods, techniques and practices have been classified as CE components that it has become unclear whether CE still has, or ever had, an identifiable conceptual core. Evans (1993) for instance mentioned that the Institute for Defence Analysis listed over sixty CE tools. Taxonomies and assessment tools classifying the components of CE have grouped practices that represent knowledge fields in themselves, like Statistical Quality Control, Knowledge Management and even Project Management (see section 2.1). This perhaps compulsive tendency to add more techniques and practices around CE was expressed in the following terms by Cleetus and Reedy since 1992:

> Different concepts are being applied to different pressure points. However, the introduction of all-encompassing terms, such as Concurrent Engineering, tends to obscure the differences. As a result the practitioner of any approach to reducing cost, improving quality or hastening the time to market can now claim adherence to the new creed of Concurrent Engineering. (Cleetus and Reddy, 1992: 1).

The myriad (perhaps exaggerated) synonyms and definitions appearing in the literature, the huge amount of methods grouped around CE, and the critics to this apparently all-embracing approach, triggered the following research question:

1. What is nowadays the meaning of Concurrent Engineering for practitioners?

It will be explored whether CE still represents a host of many different things and whether this all-encompassing perception might be inhibiting its application.

To complicate matters, terms like "concurrency" (or "concurrent") "simultaneous", "parallel", and "team work" have been used indistinctly or loosely in the literature thereby unveiling conceptual contradictions as can be seen in Table 2-10. Moreover, the term "concurrent" has been utilised in conjunction with PM and NPD to propose hybrid approaches, i.e., "Concurrent Project Management" (CPM) (Skelton and Thamhain, 1993; Lewis, 1995; Lautier, 1996; Charue-Duboc and Midler, 2002) and "Concurrent New Product Development" (CNPD) (Maylor and Gossling, 1998; Baake et al, 1999; Pawar et al, 1999; Kuar et al, 2004). Skelton and Thamhain (1993: 41) for instance, mentioned that Concurrent Engineering is "known in technical environments" noting that CNPD is "much more than teamwork psychology" probably alluding those who mistakenly believe that CE is only about work-in-team (Table 2-10).

Lewis (1995) has also used the term concurrent project management, affirming that:

> While the term *engineering* does not apply to all projects, the concepts of concurrent engineering do. For that reason I prefer to use the term *concurrent project management*". (Lewis 1995: 22).

Maylor and Gossling, justified the introduction of a new approach called CNPD commenting that:

> Concurrent or simultaneous engineering tends to infer that it is only the engineering functions that are involved. The process in reality, involves far more of the product value-stream, including suppliers, marketing personnel and customers. For this reason, the above way of working will be described as concurrent new product development. (Maylor and Gosling, 1998: 69)

As can be seen, the term "concurrency" has been used loosely on occasions, equated and juxtaposed with parallel development, related to teamwork, circularly defined as "concurrent", and apparently used to dub approaches that extend beyond engineering. Hence, there is a need for clarifying the concept of "concurrency" or "concurrent", from which the next research question was formulated:

2. How can the meaning of concurrency or concurrent be explained in order to avoid confusions with terms like parallel, simultaneous or teamwork?

Table 2-10. Confusion and contradictions regarding the terms simultaneous, concurrent, teamwork, parallel, and sequential.

Comment	Question
Concurrent Engineering is the systematic approach to the integrated, concurrent...(partial definition of Winner et al 1988, see the complete definition above)	Is there a way of defining concurrent, or concurrency without using the same term, that is, avoiding a circular definition? What does concurrent mean? Is concurrently different than simultaneously?
Two aspects of CE that distinguish it from conventional approaches to product development are cross-functional integration and concurrency. (Swink, 1998: 103)	
Concurrent development is well proven as a "best practice". But is a characterisation much more of multiple disciplines working concurrently than is a demand to push all phases and activities forward simultaneously. (Graham, 2000: 13)	
Concurrence. Product and process design run in parallel and occurs in the same time frame. (Stauffer, 1990).	Is it concurrency the same as parallel?
Time concurrency refers to activities that are performed in parallel by people of different groups. Information concurrency refers to the degree to which information is shared among the involved parties. (Loch and Terwiesch, 1998: 1033)	Are there two types of concurrency?
Overlapping of phases is called "fast tracking" in engineering/construction projects whereas it is called "concurrency" in military/aerospace projects. (Archibald, 1992: 28)	Does the meaning of concurrency depends on the industry sector?
Concurrent engineering models normally do not imply the simultaneous execution of conceptualization and implementation, but rather the join participation of different functional groups in the executing of these separate and sequential sets of activities (Iansiti, 1995: 41)	Is concurrent different from simultaneous? Is concurrent the participation of functional groups executing sequential activities?
Rohatynsky defines Concurrent Engineering as: a synergy of multi-disciplinary teams incorporating different aspects of the product life cycle into the final product, which is more efficient than traditional sequential procedures. (Rohatynsky, 1996).	Why teamwork is juxtaposed to sequential procedures? Does it mean that teamwork implies parallel procedures?

A clearer definition of concurrency may also lead to a better understanding of CE and its principal tenets which in turn would answer the following research question:

3. How can CE be better explained?

By better is meant parsimoniously, accurately, and logically coherent; attributes of good theory (Pfeffer, 1982) that do not happen to be present in the definitions listed above (Table 2-9).

2.5.2 Overlapping activities in CE and contrasting opinions about the risk of rework

The risk of rework when executing activities in parallel or overlapped (as opposed to serially) emerged as another controversial issue when studying the relationship between

CE and PM. While some authors believe that overlapping reduces the risk of rework, others sustain that it increases it.

Studies were found in the CE literature where authors affirmed that the risk of rework increases through the serial approach since it entails throwing the "ball over the fence" from the upstream to the downstream functions (Hartley, 1992; Prasad, 1996; Al Ashaab, 1999; Maylor and Gossling, 1998). They present myriad examples where for instance designs are difficult to manufacture and they have to be sent back to designers for modifications. On the other hand, when activities are developed in parallel, designers bring about easy-to-manufacture designs. Bhuiyan et al (2006) studied six historic and one on-going projects finding that the development schedule for all CE projects where activities were overlapped was reduced by 36 percent compared to projects where activities were scheduled mainly serially. Swink et al (2006) found that overlapping was positively associated to project efficiency in a sample of 137 completed NPD projects.

Probably, one of the most convincing evidence of the effectiveness of parallel development is the study developed by Clark and Fujimoto in the automobile industry (1992). Japanese companies developing activities in parallel achieved superior project lead-times than its "western" competitors which normally executed the activities serially. Japanese companies applied a simultaneous problem-solving approach consisting of overlapping activities and fostering a two-way intense information exchange between upstream and downstream functions (Figure 2-13a). This method differs substantially from to the traditional serial process where the information is passed in one-shot from upstream to downstream functions (Figure 2-13b).

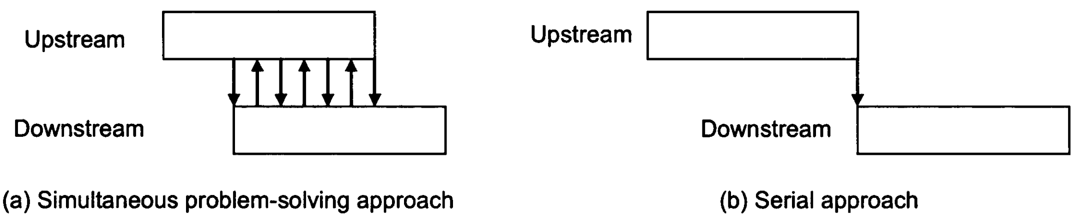

Figure 2-13. The simultaneous problem-solving approach (after Clark and Fujimoto, 1992)

Through the simultaneous problem-solving approach problems between upstream and downstream functions are detected early on and solved simultaneously by multidisciplinary teams while these problems are identified too late in the serial approach (after design freeze).

Controversially, Morris (1997) detailed a long history of project failures because of overlapping or "fast-track" practices. Eisenhardt and Tabrizzi (1995) surveyed 72 companies in the fast-pace computer environment finding that "surprisingly" careful planning and overlapping did not reduce product development time. Williams et al. (1995) warned about the "vicious circle" of parallelism because of the risk of rework that produces more delay than in the sequential procedure. Loch and Terwiesch (1998) developed an analytical model of concurrent engineering to demonstrate that one negative effect of overlapping is rework which could be reduced through communication but at the expense of communication time. Ibbs et al. (1998), using data from 108 construction projects, found that a high level of fast tracking did not generally result in any more change than non fast-tracked projects.

Contingency factors for managing overlapping have also appeared in the literature. Krishnan et al (1997) presented a model-based framework to manage the overlapping of coupled product development activities. The model and framework identify conditions under which various types of overlapping are appropriate for a pair of coupled activities. Terwiesch and Loch (1999) measured the statistical effectiveness of overlapping in reducing project completion time in 140 industrial projects finding that projects benefit more from overlap if they are able to resolve uncertainty early. Similarly, Bhuiyan et al (2004) found through simulation that overlapping is preferred in low uncertainty projects and sequential activities are preferred in high uncertainty projects.

These contrasting results appearing in the literature raised the interest in asking practitioners the following research question:

4. What is the practitioners' experience and perception about sequential and parallel development and the risk of rework?

The exploration in the field would be helpful to develop an empirical explanation of this apparently polemic issue.

2.5.3 Different criteria for sequencing activities

Interesting criteria and tools for activity sequencing appeared on the CE and NPD literature not seen before by the researcher and rarely mentioned in the PM literature. These criteria are based on activities' information inputs and outputs. For instance, Kara et al (1999) depicted three likely modes of sequencing (Figure 2-14).

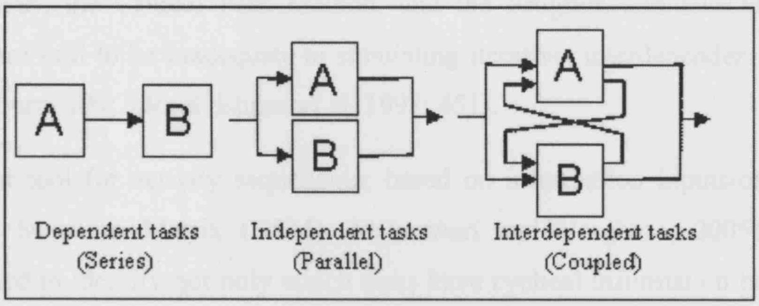

Figure 2-14. Three types of precedence relations between tasks (Kara et al, 1999)

The definitions proposed by the Kara et al (1999) are as follows:

- Dependent tasks: B cannot be started without the input of A.
- Task A and B are entirely independent and could be carried out concurrently without any interaction between them.
- A requires B's inputs, and B requires A's input, these two tasks are interdependent or coupled and they should be carried out with iterations.

The PM approach for sequencing has followed different criteria as can be exemplified in the following description (PMBOK-PMI, 2000):

- Mandatory dependencies are those that are inherent in the nature of the work being done. They often involve physical limitations (on a construction project it is impossible to erect the superstructure before the foundation has been built; on an electronic project, a prototype must be built before it can be tested).
- Discretionary dependencies are those that are defined by the project management team. They should be used with care (and fully documented) since they may limit later scheduling options.

- Applying leads and lags: the project manager's team determines the dependencies that may require a lead or a lag to accurately define the logical relationship.

These criteria seem to involve a higher degree of subjectivity than the criteria based on information input and output, especially when defining discretionary dependencies and leads and lags. Besides an apparent subjectivity, PM sequencing tools and techniques like the Gantt chart, the Critical Path Method, and the Program and Evaluation Review Technique, are said to be inadequate in simulating iterative, interdependent and coupled tasks (Blackburn, 199: 136; Krishnan et al, 1997: 451).

An important tool for activity sequencing, based on information inputs-outputs, is the Dependency Structure Matrix (DSM) (Maheswari and Varghese, 2005). The DSM method is used to identify not only which tasks have cyclical information but also which can be done sequentially and concurrently (Smith and Eppinger, 1998). According to Fine, concurrency (in the sense of overlapping) "is virtually impossible without a design structure matrix" (Fine, 1998: 186). Steward (who is considered to be the founder of DSM) and Williams affirmed that "various versions of the Design Structure Matrix have been used for engineering design by a number of Fortune 500 companies"[12]. Similarly, Browning (2001: 293) provided references of DSM application and asserted that: "the use of DSMs in both research and industrial practice increased greatly in the 1990s". Additionally, the author mentioned that the technique "had been used to manage projects since the 1960s" (Browning 2001: 293).

However, globally-known USA and UK PMBOKs (PMBOK-PMI, 2000; PMBOK-APM, 2000) neither mention this technique nor the information input-output criteria for scheduling. Likewise, the subject is practically absent in both classic and recent PM books reviewed by the researcher of this thesis. Moreover, in recent surveys investigating the level of usage of PM tools and techniques the DSM technique was not even mentioned, let alone used (White and Fortune, 2002; Milosevic and Iewongcharoen, 2004; Bessner and Hobbs, 2004). This result might be the consequence of ignoring the DSM in PM bodies of knowledge and books.

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[12] http://www.problematics.com/about.asp; accessed on August 2005.

Hence, it appeared to be interesting to investigate why PM researchers and academics have practically ignored this technique despite the extended use and purported benefits. One likely reason could be that the technique is to be applied by engineering groups rather than by project managers because of specific knowledge and skills are required. Since the literature is not clear in this respect, it was decided to explore in the field whether this assumption had empirical support. In doing so, the following question was formulated:

5. Are the design structure matrices (DSM) used by engineering groups and not by project managers?

If the empirical evidence suggested a positive answer, then the likely reasons would also be explored. However, another two possible outcomes could emerge. First, that the project managers were using the DSM technique, and second, that the engineering groups were not using the DSM technique. In both cases, the studies showing the application of the DSM and PM tools and techniques had to be questioned.

2.5.4 Parallel working versus resource smoothing

Overlapping helps to reduce the lead-time in a project, but at the same time it can create an unbalanced use of resources that otherwise (in series) would not appear. As illustrated in 2-15 (a) the overlapped figure exhibits a shorter lead-time, but it brings about peaks and valleys of resource demands (imbalance). On the other hand the sequential approach produces a smoother resource profile, but a longer lead-time (2-15 b). Thus, in CE type environments, where overlapping is pursued, the problem of resource imbalance may be exacerbated (Eden et al, 1995; Adler et al, 1995).

Takeuchi and Nonaka (1986), pioneers in recommending integrated and parallel approaches, revealed the complexity of resource management and presented clear evidence of the effect of resource imbalance:

> It requires extraordinary effort on the part of all project members throughout the span of the development process. Sometimes, team members record monthly overtime of 100 hours during the peak and 60 hours during the rest of the project. (Takeuchi and Nonaka, 1986: 145)

The trade-off parallel working versus resource smoothing has been studied since the beginning of the 1960s within the PM field (Morris, 1997: 81), and optimal solutions are still been sought nowadays (see for instance, Kavadias and Loch, 2003; Turnquist and Nozick, 2004; Joglekar and Ford, 2005).

Little research has been done about the resource imbalance problem in CE and NPD writings (Bhuiyan et al, 2004). The literature reviewed shows myriad successful cases where "before" (sequential) and "after" (parallel) Gantt charts are presented to illustrate "impressive" gains in lead-time. However, before and after resource load diagrams (to illustrate the effect on resource profile) are not presented. According to Yan and Jian (1999: 103) CE papers and books do not "place enough emphasis on the full utilization of existing resources".

Bhuiyan et al, 2004 criticized the focus on development time and overlapping and lack of attention on effort. They affirmed:

> Empirical work has found that dedicated teams reduce development time (Iansiti 1995, Scott 1997, Zieger and Hartley 1996). In contrast with our results, these studies leave the impression that the more interaction, the better. However, they do not investigate the moderating effects of uncertainty and, by focusing on just development time, ignore dedication's cost in terms of effort. (Bhuiyan et al, 2004: 1701)

Wheelwright and Clark (1992), amongst many other NPD authors, analysed the issue of resource constraints at an aggregated level, however, they "do not discuss how theses processes are affected by resource limitations" (Adler et al 1995: 460).

Using a stochastic computer model, Bhuiyan et al (2004) examined, under varying uncertainty conditions, how the key features of overlapping and functional interaction affect the performance measures of development time and effort (total person-days for a project). Although experimental their results showed that overlap may certainly reduce development time but at the expense of some other performance measure such as effort.

Interviews with experts (academics and practitioners) on CE, NPD, and PM confirmed the need for finding practical solutions for the resource imbalance problem (Lopez-Miranda, 2001). Therefore, it was decided to go to the field to investigate:

6. How do managers deal with the problem of resource imbalance in a CE-type environment where overlapping is constantly applied in order to shorten projects lead-time?

2.5.5 Two perspectives of PM and the relationship with product development

Two perspectives of PM were described in section 2.3.2, a broader and presumably more strategic perspective and a narrower execution-focused perspective. The broader perspective emerged in the 1980s as a result of an investigation of *major* projects (Morris and Hough, 1984: Morris, 1997). These projects (see examples in section 2.3.2) are clearly one-of-a-kind efforts characterised by high capital investments (millions of dollars), long development times (more than a year), and myriad persons involved (hundreds). However, many products can be developed through projects that do not have these characteristics. Examples of these *minor* projects are the development of new or modified models of televisions, tyres, glass containers, and computer peripherals.

Two additional differences between the *major* and *minor* projects are to be highlighted. Firstly, in the study of major projects the unit of analysis was a single project whereas in the study of *minor* projects several projects are normally managed at the same time. Secondly, in major projects, resource constraints were solved based on project priorities, whilst in the development of minor projects resource constraints are solved by considering also the priorities of existing on-going operations.

Therefore, the application of *the Management of Projects* broader perspective in developing new *minor* projects might be at the stake. Probably, the application of the PM execution perspective is more adequate and proportionate. It is also possible that *management by projects* or *program management,* two approaches considered within the PM broader perspective (see 2.3.2), could be more suitable to manage these kinds of projects.

Literature on NPD and CE seems to favour the application of the PM execution perspective as an integral part of an overall and strategic product development approach. In fact, the PM broader perspective was practically absent in the literature and approaches like MP, MbyP, and PgM were not considered.

According to Tatikonda and Rosenthal (2000) and Krishnan and Ulrich (2001), the development of new products can be studied under different functional perspectives such as marketing, organisation, design, manufacturing and operations management. Krishnan and Ulrich (2001) positioned PM within the operations management perspective commenting that PM decisions lie around the relative priority of the development, the timing, milestones, communication among team members, and project control and monitoring.

Brown and Eisenhardt (1995: 366) presented the development process as the "effective execution" of a rational plan (managerial) giving more emphasis to the problem solving perspective. In the same vain, Cooper (2000: 143) recommends applying "PM methods" within "the stages of the Stage Gate process" and Wheelwright and Clark (1992: 51) mentioned that PM is an approach for "getting the work done".

Moreover, some authors even claim that PM is too mechanistic or bureaucratic and centralised to be applicable in smaller or more dynamic type of projects (Blackburn, 1991; Eisenahrdt and Tabrizzi, 1995; Krishnan et al, 1997; and Coombs, 2001). This view can be the result of a stereotype created by the extended application of PM in one-of-a-kind military or aerospace projects in the 1960s. As Morris and Lopez-Miranda expressed:

> The NPD community has failed to appreciate project management as a holistic body of knowledge, perhaps influenced by the paradigmatic view that PM is either merely a subset of operations management, or is based in major projects and "projectized" organisations. (Morris and López-Miranda, 2003: 633)

Tatikonda and Rosenthal (2000: 402) mentioned that in studying NPD cross-functional perspectives at different organizational levels of analysis have been adopted such as the firm or business unit, the product development portfolio, and the individual development project. The project perspective implies that the "development of an individual product can be viewed as the organizational process of managing a project". This perspective might certainly be compared to the MP broader perspective although Morris (1997) does not describe it as a *process* but rather as an overall framework including processes, techniques, decision making and so on.

In sum, the scope of PM in developing new products did not seem to be clear and it was therefore considered necessary to develop an exploratory research to answer the following question:

7. What is the PM scope of application in developing new products?

The exploratory research would also intend to identify whether MP, MbyP or PgM are being applied and under which conditions.

2.5.6 The product manager vis-à-vis the project manager

The relationship between the product manager and the project manager emerged as a key issue in this investigation since little has been researched on this subject.

The topic first emerged when reviewing Morris' (1997) comparison between product management and project management:

> An early forerunner of project management was the development in the mid-to-late 1920s by Procter and Gamble of product management (under the term "brand management"). Product management is the practice of making a manager responsible for the overall marketing, planning and control of a brand or product. Like project management, product management stresses the integration of those functions influencing the successful outcome of a venture. It does not have the same implementation or development emphasis as project management, however, the antecedent is a strong one. (Morris, 1997: 8)

Further clarifications of the similarities and differences between project management and product management were sought but the literature was scarce. Studies analysing the role of the project or program manager vis-à-vis the product manager were also scanty. A brief review of product management and the role of the product manager are following presented to demonstrate that investigating the interfaces was important.

The need for product management seems to be clearly stated by Clewett and Stasch (1975):

> The strength of the product management concept of organization lies in the fact that it provides for a managerial focus on products or brands as profit generating systems, while at the same time it allows for flexibility in the organisational location and role of product/brand managers. Thus product management satisfies a genuine need in large, multi-product companies, divisions, or other business where it is otherwise impossible for marketing managers to plan and control closely to the

> profitability of individual major projects on a continuing basis. (Clewett and Stasch, 1975: 65)

Eckles and Novotny addressed more clearly the specific need for product managers:

> The product manager concept developed so firms could strategize, monitor and control the product mix. Procter and Gamble initiated the concept in 1927 by calling the concept brand managers. (Eckles and Novotny, 1984: 71)

The product manager provides the input for new products and, once they are created, these products are incorporated into the product mix managed by the product managers (Kelly and Hise, 1979: 328). Thus, a great deal of interface happens to exist with project managers at the beginning and at the end of the development process (Luck, 1969: 33-34; Kelly and Hise, 1979: 329).

Eckles and Novotny list a set of general duties for product managers. Many of them are clearly marketing related, like pricing, developing promo strategies, determining channels of distribution and so on. Some other duties, however, are in close contact with the job of the project manager (Eckles and Novotny, 1984: 73):

- Decide the nature of or initiate changes in on-going products.
- Initiates product re-engineering
- Initiates and controls new products conceptualization

Similarly, Dawes and Paterson (1988: 79, table 1) investigated the most relevant product manager's tasks. Many of those are also marketing oriented (forecasting, liaise with advertising agency, estimating market share, etc) and some others closely resemble project managers' at both ends of the development. Moreover, some tasks may be related with the PM broader perspective:

- Co-ordinate new product launches.
- Employ portfolio analysis in assessing performance
- Initiate product improvements/modifications
- Recommend the addition of new products and/or deletion of existing products

Authors have analysed the authority and responsibility levels of product managers (McDaniel and Gray, 1980; Eckles and Novotny, 1984; Cummins et al, 1984). The authority over the R & D function varied from company to company, ranging from none to extensive. However, it was not specified whether a project or program manager coordinated the R & D function.

Luck (1969) studied specifically the interfaces of product managers, describing the following link regarding product development:

> The product manager's involvement with new product development is dependent on the firm's organizational structure, the nature of the product itself, and the background of the manager. Where there is a separately *designated manager for new products* (italics added), the managers of current products are usually confined to planning modifications in existing products and packaging. With new products that can be designed relatively quickly, the product manager may maintain a close relationship with all stages of their development; product managers tend to have little contact with the emerging products until a market testing stage approaches. (Luck, 1969)

Although not specified, it might be assumed that the "designated manager for new products" might be the project manager and therefore it is inferred that the latter is in charge of the development while the product manager is "confined" to modifications in existing products.

From a different perspective, Bessant and Francis (1997) implemented an NPD stage-gate process in a company developing products for the information technology (IT) industry. They present the NPD process overview showing both the roles of the product manager and the project leader. In this process overview, the product manager is in charge of presenting the information at each stage, from stage 0 (Evaluate Requirement) to stage 2 (Order Review). After approving stage 2 a project leader takes over the function of presenting the information from stage 3 (detail project plan) up to stage 8 (Approve Manufacture). At every stage, decisions are made by executives and directors, and not by the product manager nor by the project leader, except for stage 5 (Commit to Mass Production) where the "decision maker" is the project leader (Bessant and Francis, 1997: 193, Fig. 1). Hence, the process shows a product manager doing marketing presentations and a project leader doing development presentations and taking the decision to commit to mass production. Unfortunately, the authors do not discuss these roles and less so their interfaces, that is, how the product manager hands over the project to the project leader.

Several studies have analyzed the interface between marketing and R & D in product development (Griffin and Hauser, 1996; Song and Parry, 1997; Atuahene-Gima and Evangelista, 2000). However, these studies addressed the relationships between functional managers and specialists (e.g., marketing people and scientists or technicians) without considering the relationship between the product manager (on the marketing side) and the project manager (on the R & D side).

Organizationally speaking, most researchers have found that product managers report to a marketing or commercial manager. Handscombe (1992: 72, fig. 3.2), for instance, depicts two kinds of product managers, both reporting to a commercial director. Interestingly, one of them is called "New Products Manager" and is described as the person responsible for leading the whole development program, from identifying product needs up to product launch (Handscombe, 1992: 77).

Clark and Fujimoto (1992) described the strong role of the "heavy-weight product manager", a relevant figure leading the development of new car models in the automobile industry. The authors use literally the world "product manager" but the role seems to embrace the typical activities of a project director or program manager, as can be inferred from the following observation:

> Heavy-weight product managers are usually senior in the organization, often at the same or higher rank as the heads of the functional groups. Some of their work occurs through liaison representatives, but the liaison personnel themselves are "heavier" than in the lightweight system. In addition to working directly with the project manager liaison people serve as local project leaders within their functional groups" (Clark and Fujimoto, 199:255)

Clark and Fujimoto found that heavy-weight product managers were highly market-orientated and had the following additional characteristics (Clark and Fujimoto, 1991: 256-257):

- Coordination responsibility in wide areas, including production and sales as well as engineering.
- Coordination responsibility for the entire project period, from concept to market.
- Maintain direct contact with customers.

- Possess market imagination and the ability to forecast future customer expectation based on ambiguous and equivocal clues in the present market.

Apparently, the so-called "heavy-weight product manager" seems to fulfil the role of the product and the project manager simultaneously. The "heavy-weight product manager" may correspond to the figure of the "New Products Manager" described by Luck (196) or Handscombe (1992), but it may also encompass the figure of "the manager of the projects", described by Morris in reference to the broader MP perspective.

In any case, the interfaces or relationship between the product and project/program manager seem to be important, however *how* this relationship works is still a topic that has not been sufficiently investigated. Therefore, the subsequent research question was posited:

8. What is the relationship between the product manager and the project/program manager during the development of new products?

An exploration in the field may uncover more clearly what the corresponding hierarchical positions within an organization are; how they interact with each other; how one hands over the project or the product to the other; or whether there is one "strong" role that overtakes both functions. It should be sought what the company and environmental conditions are in these different situations.

2.5.7 Contradictory classification systems

Practices, methods, tools and techniques have been grouped around CE, NPD, and PM presumably to describe its scope and facilitate its application. These grouping systems have been called variously, classification systems, frameworks, taxonomies or assessment tools but they happen to be confusing when compared to each other as will be seen next.

CE assessment tools are instruments where classified questions are put together to measure the level of CE implementation. Many of these instruments include questions about PM and NPD (Veness et al, 1996; Van Landegem, 2000; Al-Ashab and Valdepeña, 2000; Ainscough et al, 2003). Ainscough et al (2003) for instance, developed a CE classification that includes an NPD process component (dubbed NPI) and a PM component (Figure 2-15).

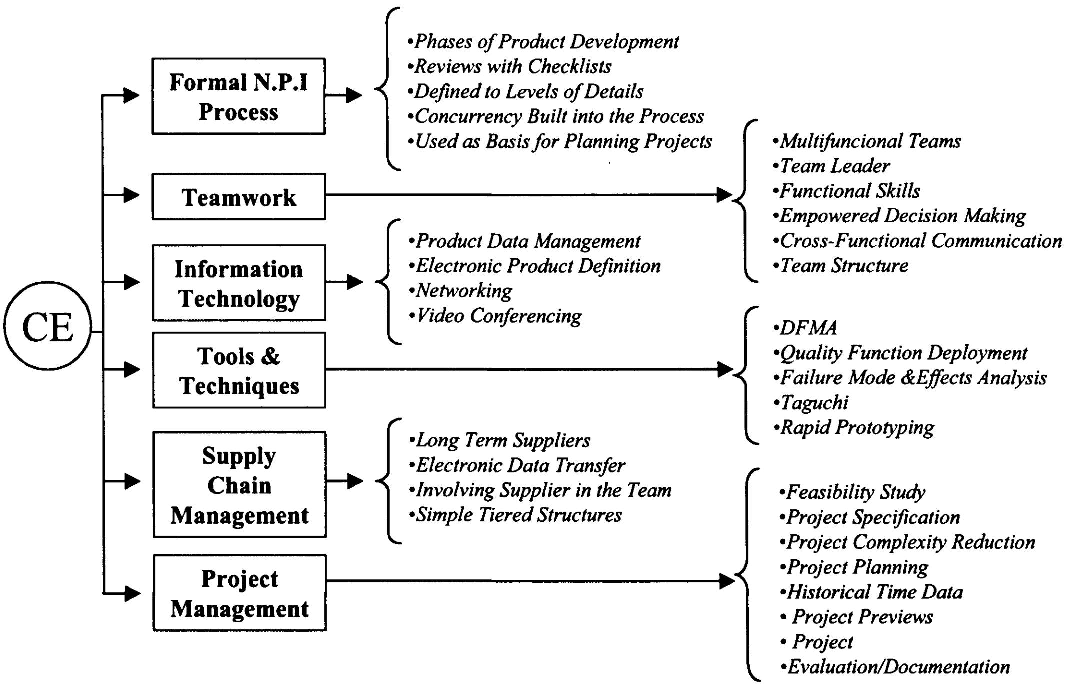


Figure 2-15. CE assessment model (Ainscough et al, 2003)

At least two issues arose when studying these instruments: firstly, it is not explained how and why only some PM techniques were selected (and why not others), and; secondly, the selected PM techniques seem to be too generic to be objectively assessed. For instance, the CE assessment tool of Venness et al (1996) included an issue broadly called "project planning and tracking tools" without defining what tools (the PMBOK-PMI (2000) for instance counts around 50). Van Landeghem (2000) incorporated a different but equally generic element called "progress control", described literally as "use of project management techniques".

Maylor and Gosling (1998) developed a survey asking managers about the most useful CE techniques and most managers answered that PM was one of them, however, it is difficult to conceptualise PM as a single technique as noted by the authors:

> As can be seen, project management comes out as the most used technique (although it should be seen as a group of techniques rather than a single one). (Maylor and Gosling, 1998: 71)

On a different and contrasting perspective CE and NPD have been classified as PM subsets. Kloppenborg and Oppfer (2002) built a framework to review, classify, and catalogue PM citations in journals since 1960 (Table 2-11). The framework's first set of citations relate the nine PM areas of the PMBOK-PMI (2000) the second set relates the application of PM to different industries, and the third set relates process areas. As observed in table 2-11, CE was classified as a "process area" and NPD was classified as an "application area" of PM.

Table 2-11. Project management keywords (Kloppenborg and Oppfer, 2002) (Bold text added by the researcher)

Knowledge areas	Application areas	Process areas
Integration Scope Time (schedule) Cost Quality (performance) Human resources Communications Risk Procurement	Aerospace (defence) Construction Information systems (information technology) **New product development (research and development)** Pharmaceutical Utility (energy) Government Telecommunications (electronics) NASA Consulting Manufacturing Education General Teams	Life cycle Initiate Plan Execute Control Close Organise Motivate Direct Lead Benchmark Reengineer **Concurrent engineering (simultaneous engineering)** Improve

NPD frameworks have also included the other approaches. Rosenthal and Tatikonda (1992) carried out a study examining different processes to develop new products in 7 companies, from inception to the customer delivery. The researchers developed an integrated framework (Figure 2-16) wherein PM is included as "Project planning and management". The authors recognised the need for further analysis and discussion regarding the participation of PM in NPD.

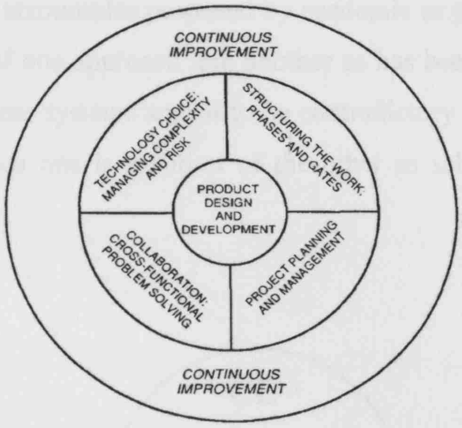


Figure 2-16. An integrated view of product design and development. (Rosenthal & Tatikonda, 1992)

Tennant & Roberts (2003) developed a framework for "NPI" best practice based on primary, secondary, and tertiary criteria (Table 2-12). The researchers classified program/project management as part of the NPI process. Concurrent Engineering and other techniques were classified just as "methods".

Table 2-12. Primary, secondary, and tertiary criteria for NPI best practice. (from Tennant and Roberts 2003: 81) (Bold text added by the researcher)

Primary	Secondary	Tertiary
1. Organisation	1. Cross functional management 2. Project team approach	1. Cross functional negotiation (Other five criteria)
2. **NPI process**	3. **Programme management** 4. Approval and review process 5. Decision making	7. Integration of product introduction process and project/programme management 8. Links between major phases (Other six criteria)
3. Knowledge management	6. Intensive communication 7. Training 8. Centralised support	11. Review process established (Other three criteria)
4. Methods	9. **Concurrent engineering** 10. Techniques	19. Fast development process 20. Overlapping product introduction phases 21 Supplier involvement (Other five criteria)

Classification systems or taxonomies proposed by academic or professional communities also show the inclusion of one approach into another as has been highlighted in sections 2.1.2, 2.2.2 and 2.3.3. These systems appear to be contradictory as one includes the other thereby implying that each one is a subset of the other as schematically illustrated in Figure 2-17.

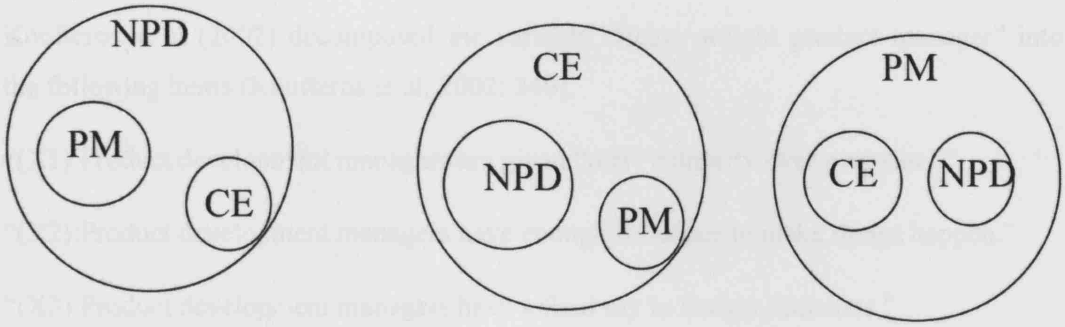


Figure 2-17. Contradictory CE, NPD, and PM classification systems?

Since this apparent contradiction inhibits a proper understanding of the relationship between CE, NPD and PM, the following research question was posited:

9. How can it be explained that CE, NPD, and PM classification systems subsume each other?

2.5.8 Unclear cause and effect relationship

One of the main questions leading this research was whether CE, NPD, and PM have a cause-effect relationship, that is, whether one approach causes a positive or catalytic effect to the others. Understanding this relationship, if any, might help managers to decide whether one approach should be a precursor of the others and therefore to plan and optimise implementation efforts and investments. Unfortunately, propositions on this matter are scanty, confusing or merely speculative in the literature.

Koufteros et al (2002) proposed and tested a model showing that heavy-weight product development managers have a positive effect on the use of concurrent engineering because of their integrative and motivational role and their ability to take decisions that cut across functions (Figure 2-18). The hypothesis posited by these authors and the results after the survey and data analysis are as follows:

"H1a. Heavyweight product development managers have a positive effect on the use of concurrent engineering." (Koufteros et al, 2002: 335). Result: Confirmed, statistically significant (Koufteros et al, 2002: 343)

Koufteros et al (2002) decomposed the variable "Heavy-weight product manager" into the following items (Koufteros et al, 2002: 340).

"(X1) Product development managers are given "real" authority over personnel."

"(X2) Product development managers have enough influence to make things happen."

"(X3) Product development managers have a final say in budget decisions."

"(X4) Product development managers have a final say in product design decisions."

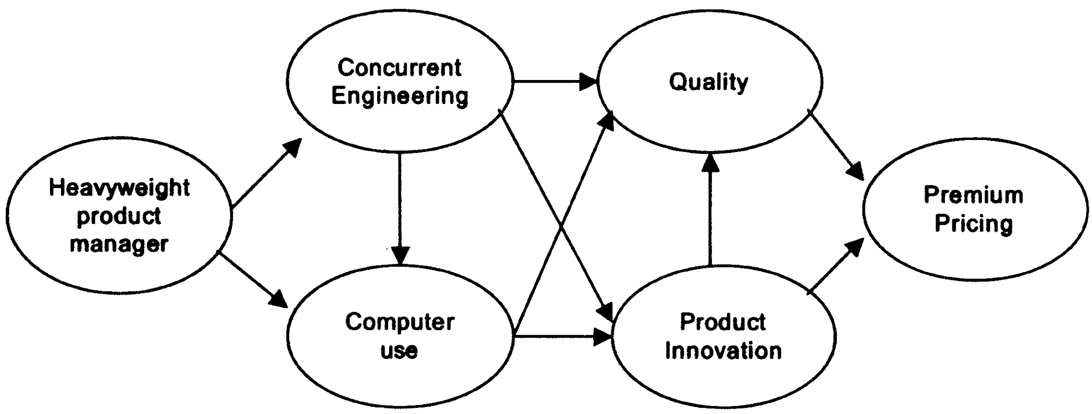


Figure 2-18. Causal model showing that heavy-weight project managers impinge on CE (After Koufteros et al 2002).

These items seem to indicate that "light-weight" product managers or project coordinators do not greatly influence CE. Examples of the variables used by Koufteros et al (2002: 340) to measure CE compliance are:

"(X5) Product and process designs are developed concurrently by a group of employees."

"(X6) Much of process design is done concurrently with product design."

"(X7) Product development activities are concurrent."

"(X8) Product development group members share information."

"(X9) Product development group members represent a variety of disciplines."

Tatikonda and Rosenthal (2000) proposed a model that unveils how CE, NPD, and PM could be related (Figure 2-19). According to this model, project execution methods, i.e., formality, project management autonomy, and resource flexibility, impinge on project execution success.

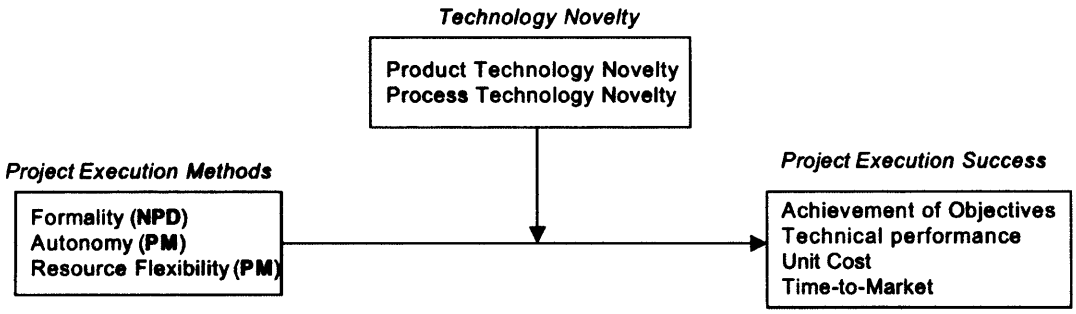


Figure 2-19. Conceptual framework of project execution effectiveness in product development projects (bold added) (After Tatikonda and Rosenthal, 2000)

Formality occurs via the utilization of structured NPD-type processes like Cooper's stage-gate process or Wheelwright and Clark funnel model, both already described in this thesis. Autonomy is described by the authors as the "unit's ability to choose the manner in which the work will be accomplished" (Tatikonda and Rosenthal, 2000: 406), that could be the PM strategy. Resource flexibility is defined as "the flexibility in re-allocation of project resources", a subject traditionally studied in PM under the issue of resource assignment and balancing. The hypotheses proposed by the authors and the corresponding results are as follows:

"Hypothesis 1. Projects having a greater degree of formality have higher levels of project execution success." (Tatikonda and Rosenthal, 2000: 406).

"Hypothesis 2. Projects having a greater degree of project management autonomy have higher levels of project execution success." (Tatikonda and Rosenthal, 2000: 407).

"Hypothesis 3. Projects having a greater degree of resource flexibility have higher levels of project execution success." (Tatikonda and Rosentahl, 2000: 408).

The three hypotheses were confirmed, the authors found a "direct, positive relationship" (Tatikonda and Rosentahl, 2000: 413).

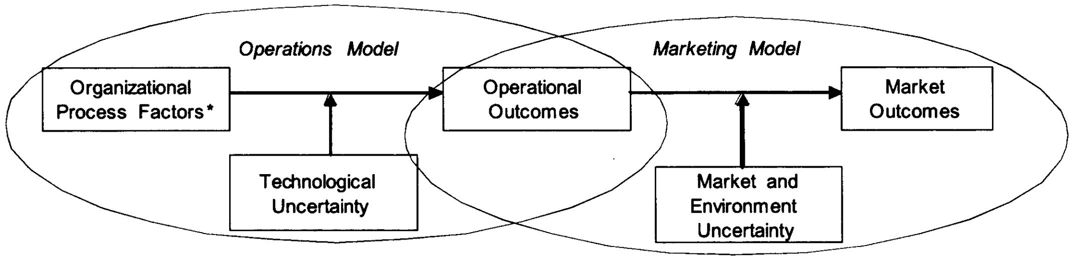
Tatikonda and Montoya-Weiss (2001) proposed a model showing cause-effect relationships between organisational process factors, operational outcomes and market outcomes, which are in turn affected by technological uncertainty and external uncertainty (Figure 2-20). The organizational process factors include process concurrency, process formality, and process adaptability.

The authors define process concurrency as "the degree of simultaneity in the design engineering and manufacturing engineering efforts" (Tatikonda and Montoya Weiss, 2001: 155). Process formality is referred to as "the existence of an overall organizational process and structure of the project" (Tatikonda and Montoya Weiss, 2001: 155), a concept related to NPD processes. Finally, process adaptability is referred to as the "flexibility during the project to meet emerging circumstances, and represents discretion available to project management" (Tatikonda and Montoya Weiss, 2001: 155), which embodies PM concepts. The hypotheses proposed by the authors, concerning this research, are:

"Hypothesis 1 projects having greater process concurrency have higher achievement of operational objectives." (Tatikonda and Montoya Weiss, 2001: 156).

"Hypothesis 2 projects having greater process formality have higher achievement of their operational objectives." (Tatikonda and Montoya Weiss, 2001: 156).

"Hypothesis 3 projects having greater process adaptability have higher achievement of operational objectives." (Tatikonda and Montoya Weiss, 2001: 156).



* Consisting of process concurrency (CE -related), process formality (NPD related), and process adaptability (PM-related).

Figure 2-20. Conceptual framework integrating operations and marketing perspectives of product development (after Tatikonda and Montoya Weiss, 2001) (Note added).

The results indicated that hypotheses 1 and 2 were strongly supported, while hypothesis 3 was partially supported (Tatikonda and Montoya Weiss, 2001: 164). The authors concluded that "considered jointly, the three process factors are simultaneously beneficial" (Tatikonda and Montoya Weiss, 2001: 164).

The two previous models (Figure 2-19 and Figure 2-20) proved that CE, NPD, and PM elements have a positive impact on product development success. However, this research pretends to explore which of these three has an impact on the others (Figure 2-21), so that managers can channel their efforts when trying to implement or improve any of these practices. Hence, complementary questions might be addressed, like, does formality (NPD) influence adaptability (PM) or *vice versa*? Does concurrency (CE) enhances formality (NPD) or *vice versa*?

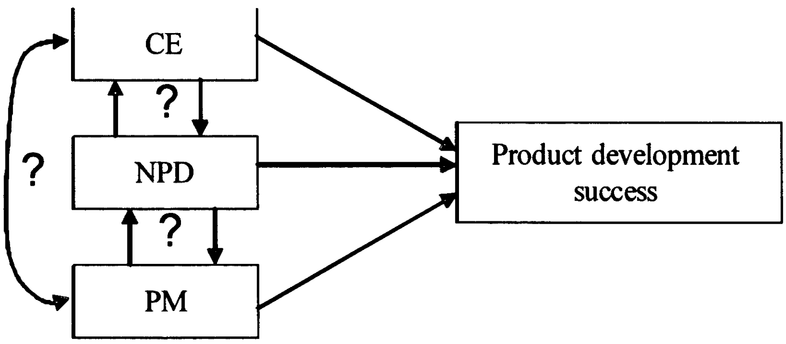


Figure 2-21. Hypothetical causal model between CE, PM and NPD and questions that need to be answered.

Researchers have proposed PM as an "agent" to implement CE. Ainscough et al (2003) identified and applied PM as a change-management tool to implement CE (see Figure 2-15). Pawar et al (2002: 85) developed a CE implementation framework (see previous chapter) commenting that "it could be used as part of a guided tour for (say) the project manager". Abdalla (1999: 258) stated that dealing with CE projects requires project management strategies. Levene and Goffin (1997: 5) affirmed that "without effective project management, CE can be difficult to apply".

These opinions suggest that PM should precede CE implementation projects, thereby implying that a PM framework has to be in place before starting CE endeavours, or at least implementers should be skilled in PM to ensure success. A hypothetical causal model reflecting this influence is shown in Figure 2-22. The corresponding hypothesis or proposition would say something like: the greater the application of PM tools and techniques, the higher the possibilities of CE project implementation success, which in turn improves product development outcomes.

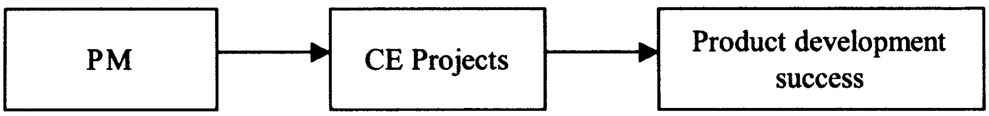


Figure 2-22. Hypothetical causal model between PM and CE.

Other authors suggested that CE improves PM practices. Thamhain (2004), who has developed considerable research on PM and has recently studied CE environments, affirmed the following:

> Concurrent engineering provides the managerial framework for effective, systematic, and concurrent integration of all functional disciplines necessary for producing the desirable project deliverables, in the least amount of time and resource requirements, considering all elements of the product life cycle. (Thamhain, 2004: 452-53)

On a similar note, Morris (1997) considered that CE would be an important approach for the new and broader discipline of the management of the projects. Hartley (1992: 24) affirmed that CE is a "relatively new approach to project management with a number of specialised techniques to optimise the design activity". Accordingly, PM practices happen to improve considerably if CE is adopted as a managerial framework or as a new approach, thereby implying that CE principles, tools and techniques should be learnt by project managers. The causal model explaining this likely relationship is shown in Figure 2-23 and the corresponding hypothesis would be proposed as: the greater the application of CE principles, tools and techniques, the better the PM practices and therefore the higher the possibilities of product development success. Unfortunately, the model displayed in Figure 2-22 seems to be in contradiction with the model proposed in Figure 2-23.

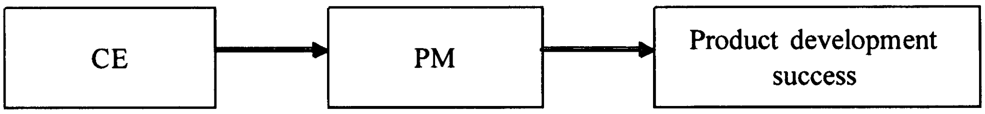


Figure 2-23. Hypothetical causal model between CE and PM

Similarly, CE practices have described to be decisive in improving NPD practices to such an extent that authors have proposed the term *Concurrent* or *Integrated* Product Development instead of simply NPD (Khury and Plevyak, 1994; Pawar et al 1998; Gerwing and Barrowman, 2002; Büyüközkan et al, 2004). In this case a hypothetical causal model between CE and NPD could be proposed (Figure 2-24) and the corresponding hypothesis would probably say: the greater the application of CE principles, the better the NPD practices and therefore the higher the possibilities of product development success.

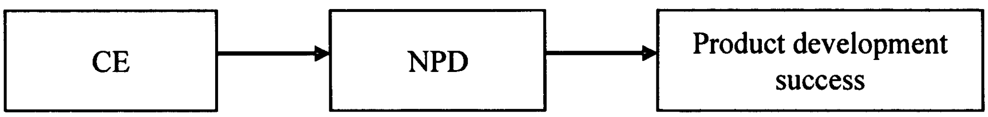


Figure 2-24. Hypothetical causal model between CE and NPD

As can be seen from this review, the scarcity of the causal models explaining the relationship between CE, NPD, and PM, as well as the different perspectives suggested by a number of authors made it difficult to understand whether one approach enhances the others or whether one should take precedence over the others in order to optimise implementation efforts. Therefore, an exploratory study to set basic relationships and propositions seemed to be justified and the subsequent research question was expressed as follows:

10. What is the cause-effect relationship, if any, between CE, NPD, and PM?

2.5.9 Lack of integrated process models

NPD has been defined and modelled as a process consisting of several stages from product idea to product launch (e.g., Cooper, 1994). Likewise, PM has been conceptualised as a process (CRMP, 1999) or a series of sub-processes along the project life cycle (PMBOK-PMI, 2000) and CE has also been considered a process (Thamhaim, 2004: 451; Bowonder et al, 2004: 372). Despite this common conceptualization, few process models[13] showing the inter-relationship between the three approaches were found in the literature. Two of the most common models will be explained alongside issues that need to be clarified.

Wheelwright and Clark (1992) developed a process model to "revolutionize" product development (Figure 2-25) which includes PM and CE. The process consists of first assessing the market and firm's technology assets. Then, the company should develop goals and objectives, and the corresponding aggregate plan. After these steps, Project management and execution methods should be applied, ending the process with a final step to evaluate lessons learnt. Project management and execution includes "detailed design, engineering problem solving, building and testing of prototypes, marketing planning, process planning and development, and manufacturing ramp-up" (Wheelwright and Clark, 1992: 51). CE does not appear explicitly in the model but is conceptualised by the authors as a set of techniques for executing activities in parallel during the design process, like CAD/CAM and DFM.

Although the model is a solid and cogent construct, a particular interface is not clearly explained: the starting and ending point of the project management sub-process. In other

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[13] By process models it is meant graphic constructs showing inter-connected sub-processes or steps along the project or the product life cycle.

words, it is not clear *when* during the process the project managers and their teams are engaged and disengaged. For instance, activities like project definition, scoping, and staffing are included in two different steps in the model (see Figure 2-25), within the Aggregate Project Plan (Wheelwright and Clark, 1992: 86) and within the Project Planning and Execution (Wheelwright and Clark, 1992: 135, exhibit 6-1).

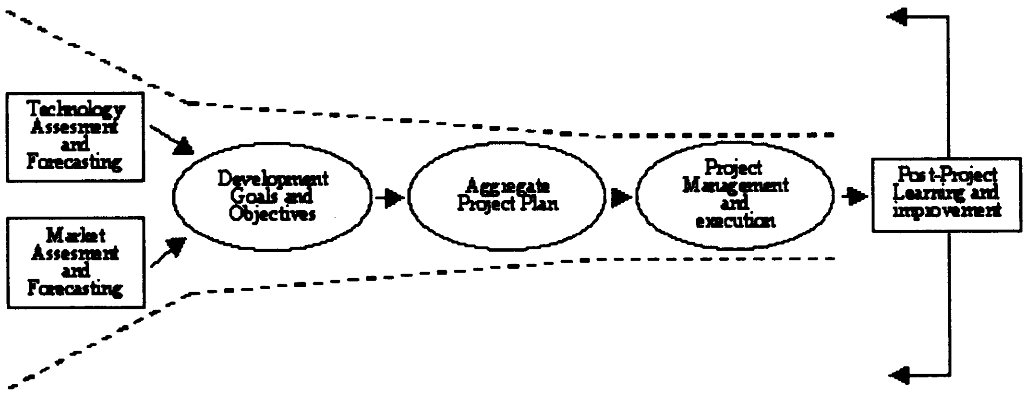

Figure 2-25. Product development strategies and PM (Wheelwright and Clarck, 1992).

At the other end, Wheelwright and Clark wrote practically nothing about project closure and hand over to production or services. Maylor and Gosling (1998) considered that more should be done to investigate the timely involvement of the staff along the product life cycle since:

> This is the kind of operational detail that is absent from the majority of the literature. For the manager, however, such detail is vital. (Maylor and Gosling, 1998: 71)

Thus, both the starting and ending points of PM in the process to develop new products seemed to be interesting topics for research and therefore the following research question emerged:

11. When should the project manager and the project team be engaged and disengaged during the process to develop new products?

A relatively different model is the Advanced Product Quality Planning and Control Plan (APQP) guide to product design and development which has been announced as an appropriate framework for CE (Al Ashaab, 1999; Elsmar, 2003; and Bobreka and Sokovicb, 2005) and contains an NPD-type process model and PM elements.

The APQP is a "structured method for defining and establishing the steps necessary to assure that a product satisfies the customer" (APQP 1994: 3). The APQP is a reference manual for applying the QS 9000 Quality System developed by Ford, GM, and Chrysler (APQP, 1994). The process model and its basic stages are displayed in Figure 2-26.

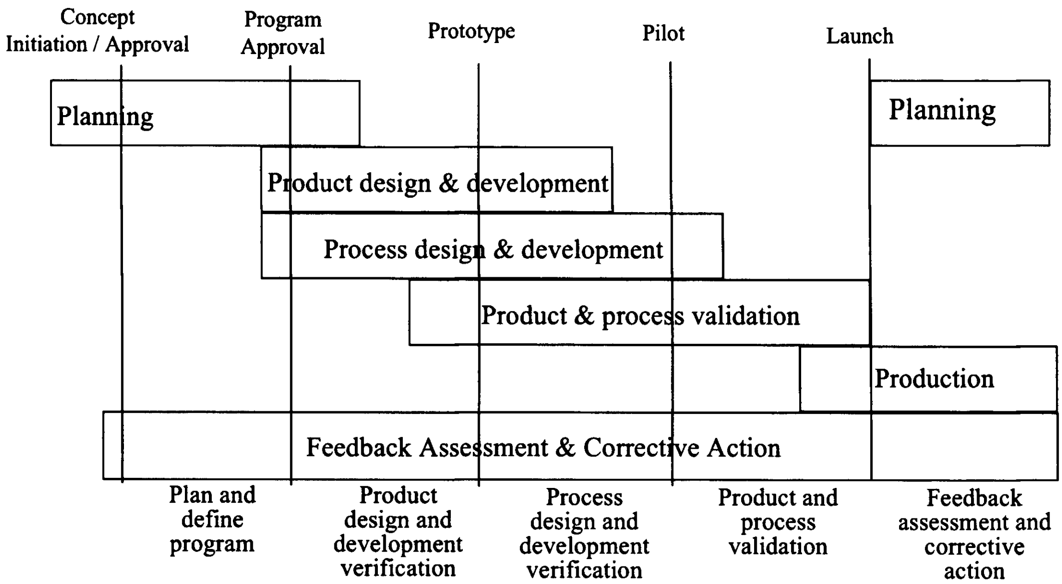

Figure 2-26. The APQP process model (APQP 1994: 5)

The APQP outlines the following "fundamentals of product quality planning" (APQP, 1994: 3-5)

- Organise the team
- Define the scope
- Team-to-team
- Training
- Customer and supplier involvement
- Simultaneous engineering
- Control Plans

- Concern resolution
- Product quality timing plan
- Plans relative to the timing chart

The guide urges providers to integrate multidisciplinary teams, called "Product Quality Planning Teams", to carry out the design and development process. Several tools are recommended for investigating customer needs and expectations like QFD, and for improving quality product and reducing product development lead-times like FMEA, DFM, and DFA.

This brief description confirms that the APQP includes elements that have been included in the CE taxonomies and frameworks reviewed in the literature (e.g. multidisciplinary teams, simultaneous engineering, customer involvement, and tools like QFD, FMEA, and so on). Moreover, the APQP (as well as CE) emphasises front-end planning as "the three first quarters of the cycle are devoted to up-front product quality planning through product and process validation" (Gruska and Cherry, 2005: 32).

The document also prescribes the use of PM techniques and practices like the "Product quality timing plan" in the following terms:

> A well-organised timing chart should list tasks, assignments, and/or other events. (The Critical Path Method may be appropriate; reference Appendix B). Also, the chart provides the planning team with a consistent format for tracking progress and setting meeting agendas. To facilitate status reporting, each event must have a "start" and "completion" date with the actual point of progress recorded. Effective status reporting supports program monitoring with a focus on identifying items that require special attention. (APQP, 1994: 5)

Tthe APQP definition of "success" encompasses directly the PM definition of success under the PM execution perspective (quality, time, and cost), as can be concluded from the following clause:

> The success of any program depends on customer needs and expectations in a timely manner at cost that represents value. (APQP, 1994: 5)

The APQP contains NPD characteristics like the process model depicted in Figure 2-26 which is a representation of an NPD process along the product life cycle. This process includes the definition and execution of the steps necessary to ensure that a product or service satisfies customer needs (Gruska and Cherry, 2005).

This review shows that the APQP is a process model containing CE, NPD, and PM inter-related elements suggesting that it could be a complete framework for developing new products. This suggestion was explored in this research for confirmation purposes and also to explain in more detail how it works. In doing it, the following research question was posited:

12. Is the APQP a suitable and complete model for developing new products because it combines CE, NPD, and PM elements?

In general, the scarcity of process models showing the relationship between CE, NPD and PM may represent an opportunity for research or, unlike the opinion of authors, it may be an indication that either CE, NPD, or PM are not processes in strict sense and therefore they cannot be represented in this form. This research addressed both possibilities by raising the following research question:

13. How can the relationship between CE, NPD, and PM be explained through interlinked process models?

2.5.10 Essence, purpose, and theoretical basis

The very essence of CE was conceptualised in many not always similar forms. It has essentially been classified as *an approach* by Winner et al (1988) and Cleetus (1992) but contradictorily Pawar et al (2002) affirmed that, more than a single approach, CE is a multitude of approaches. On the same vein, Veness et al (1996) pointed out that it is more an overall *strategy* than a unified methodology. Other authors consider that CE is a *philosophy* of working (e.g., Jo et al, 1991 and Skalak et al, 1997). Ellis (1992) conceptualised CE as an *environment,* whereas Thamhaim (2004: 451) and Bowonder et al (2004: 372) conceived CE as a *process*. At its simplest, CE has been referred just as a *technique* "to increase the number of activities in parallel" (Mileham et al, 2004).

NPD has essentially been defined in fewer forms than CE, but there are some striking similarities and differences. Like CE, NPD has been conceptualised as a *process* by the Product Development Management Association (PDMA, 2003a) and Cooper (1994), and as an organisational process by Tatikonda and Rosenthal (2000). Krishnan and Ulrich (2001) defined NPD as a *transformation* of a market opportunity into a product available for sale.

PM has also been conceptualised in different forms. On the practitioners side (e.g., PMBOK-PMI, 2000) PM is the *application* of knowledge, skills, tools, and techniques to project activities. This source also conceptualises PM as a *process* composed of a set of sub-processes or process groups (PMBOK-PMI, 2000: 29). Gouse and Stickney (1988) consider that PM is the application of the *systems approach* to the management of complex projects. From a different perspective, PM has been conceptualised as a *discipline* by Morris (2002) and Bredillet (2004). Controversially, Zwerman et al (2004) concluded that PM is not a profession in the sense of a professional occupation, like nursing, law or medicine. Bredillet (2004) also considers PM as an *art,* a *science,* and as a *knowledge field* in itself.

In synthesis, CE, NPD, and PM have essentially been conceptualised or classified in many different forms. This diversity raised the ensuing research question:

14. How can CE, NPD, and PM be essentially conceptualized so that they can be comparable?

Trying to define *what* in essence CE, NPD, and PM are led inexorably to question their ultimate goal or purpose (teleology), i.e., the *why*. They suppose to exist to solve a problem or to bring about benefits. However, as reported in the literature review, they can be seen as problem-solving approaches for developing new products and their benefits happen to be very similar (e.g., improving time, cost and quality). Thus, the following question was posited:

15. What is the difference in purpose, if any, between CE, NPD, and PM?

An answer to this question would help to select the appropriate approach for the corresponding problem.

The readings on CE, NPD, and PM also revealed interesting differences as to the nature of their knowledge. Firstly, more papers analysing past, present and future research were found on PM than on NPD, whereas CE writings on this topic were scarce (only two were found, see chapter 2). PM researchers seemed to be more interested in knowing, from an existentialist perspective, where the field comes from and where it goes. The second difference relates readings about the search for theoretical bases underlying the field. In this respect, PM authors were found to be more prolific than their CE and NPD colleagues. Finally, the third difference pertains to the application of empirical or so-called "scientific methods". In this case, NPD research seemed to adhere more rigorously to empirical scientific methods than CE, and CE more than PM. These three differences happen to be related to a kind of epistemological *maturity* of the knowledge field, meaning by maturity an intellectual evolution or a philosophical introspection up to the level of the self-questioning and self-critique (as mankind). Hence, the following research question was posited as follows:

16. Do CE, NPD and PM have different levels of maturity?

Finally, the literature review revealed that CE, NPD and PM have common underlying theories. CE is described as being at the intersection of engineering-design, information processing and social sciences (Wognum et al 2004). NPD might be nurtured by theories developed in organisation, marketing, operations management, and design fields (Krishnan and Ulrich, 2001). NPD has also been analysed as an information process phenomenon (Gerwin and Barrowman, 2002; and Clark and Fujimoto, 1992). Controversially, a group of NPD researchers adopt a project perspective and note that "the development of an individual product can be viewed as the organizational process of managing a project" (Tatikonda and Rosenthal, 2000: 402). PM research might be supported by two main theoretical traditions:

> The first tradition with intellectual roots in the engineering science and applied mathematics, primarily interested in the planning techniques and methods of project management. The other tradition with its intellectual roots in the social sciences, such as sociology, organisation theory and psychology, especially interested in the organisational behavioural aspects of project organisations. (Söderlund, 2004: 185)

Morris (2002) refers to this combination as the symbiosis of hard and soft systems and the PMI-USA fellowship commonly use the terms "art" and "science" of PM. Likewise, some authors assert that the theoretical basis of PM is in the systems theory (Cleland and King, 1983, Morris, 2002) and in Operations Management (Krishnan and Ulricht, 2001).

According to this theoretical *mosaic* it is also possible to believe that, instead of knowledge fields, CE, NPD, and PM are sub-specialities or *cross-disciplines* whose underlying theories interfere with each other. However this proposition leaves the door open to believe that they do not have a strong theoretical basis but rather many theories imported from different fields. The literature review indicates that this diversity has apparently caused a lack of theoretical consensus which unfortunately complicates the study of the field. Research lines, for instance, are astonishingly ample and disperse in the three fields going from the social science to engineering fields or informatics.

CE methods, tools and techniques have been increasing throughout the years. Moreover, its scope has been purposefully extended along the product life cycle, not only to engineering, but to also include suppliers and customers in an extended value chain (the extended enterprise). Professional sub-communities have even welcomed new topics within the subject as can be appreciated in the following comment:

> These are likely to remain key topics in future years, but the ICE community should remain open to a new and emerging topics and encourage these to flourish in future conferences, just as Knowledge Management area has been allowed to grow. (Lettice et al, 2004: 135)

NPD has also been extending its scope, yet to a lesser extent than CE. As described in Chapter 2, what started with studies of performance indicators has been growing to include PM typical research topics. For instance, Thieme et al (2003) analysed the evolution of NPD research and set directions for further research that clearly interact with PM:

> We move past the questions "How do the environment and our company's strengths and weaknesses affect our new product strategies?" and "How do we structure our organization to maximize our effectiveness in NPD?" to begin to answer the question "What project management characteristics will foster the development of new products that are more likely to survive in the market place?". (Thieme et al, 2003: 105)

PM is in the same expanding condition. The first studies positioned the subject within Operations management addressing scheduling methods (Archibald, 1992; Shenhar and Dvir, 2004) or closely related to the holistic systems approach (Cleland and King, 1983; Morris, 1997). Nowadays authors position PM in a more strategic and extended purview along the product life cycle. However, Morris and Pinto have reflected on this extended scope and questioned whether the essence or the scope is not at stake, thereby at risk of becoming an all-embracing subject:

> As a result, project management remains in danger of becoming a term with multiple meanings and multiple processes, depending upon the type of project undertaken (construction, R&D, event planning) and the professional association addressing it (IRI, ASCE, PMI, IEEE, and so forth). (Pinto, 2002: 36)

> Project Management, and particularly those who teach and consult to them, generally take only middle-management, tools and techniques view of the subject. Few address the larger, more strategic issues that crucially affect the success of projects. The question thus needs to be posed: what should the proper scope of the subject of managing projects be? (Morris, 1997: 217)

According to the comments above, it is speculated whether CE, NPD, and PM could be in danger of *losing identity* as a result of ever-expanding scope or of theoretical dispersion. From these reflections emerged the final theoretical research question:

17. Is the expanding scope of CE, NPD, and PM a danger for the development of the subject?

2.5.11 Summary and list of research questions

Literature on CE, NPD, and PM is abundant, however research addressing their interfaces is scarce and reveals contradictions, wherein lie the main research issues of this thesis.

CE happens to be an all-embracing term that is difficult to synthesise thereby complicating the task of finding a relationship with NPD and PM. This relationship does exist, however, in many aspects. There are common terms, different approaches for sequencing tasks, and similar roles, all of which require clarification. Furthermore, communities of practice around CE, NPD, and PM have created taxonomies, processes and causal models that either interact or interfere each other. The literature reveals poor cross-referencing between authors of the corresponding professional communities.

The comparison between CE, NPD, and PM, raise questions of a more essential nature such as what they are and what their purpose is. These questions yielded further questions regarding underlying theories, the expansion of knowledge in each field, and maturity.

In sum, the comparative analysis raised the following seventeen research questions:

1. What is nowadays the meaning of Concurrent Engineering for practitioners?

2. How can the meaning of concurrency or concurrent be explained in order to avoid confusions with terms like parallel, simultaneous or teamwork?

3. How can CE be better explained?

4. What is the practitioners' experience and perception about sequential and parallel development and the risk of rework?

5. Are the design structure matrices (DSM) used by engineering groups and not by project managers?

6. How do managers deal with the problem of resource imbalance in a CE-type environment where overlapping is constantly applied in order to shorten projects lead-time?

7. What is the PM scope of application in developing new products?

8. What is the relationship between the product manager and the project/program manager during the development of new products?

9. How can it be explained that CE, NPD, and PM classification systems subsume each other?

10. What is the cause-effect relationship, if any, between CE, NPD, and PM?

11. When should the project manager and the project team be engaged and disengaged during the process to develop new products?

12. Is the APQP a suitable and complete model for developing new products because it combines CE, NPD, and PM elements?

13. How can the relationship between CE, NPD, and PM be explained through interlinked process models?

14. How can CE, NPD, and PM be essentially conceptualized so that they can be comparable?

15. What is the difference in purpose, if any, between CE, NPD, and PM?

16. Do CE, NPD and PM have different levels of maturity?

17. Is the expanding scope of CE, NPD, and PM a danger for the development of the subject?

These issues and questions constituted the theoretical framework of this thesis and a research endeavour was undertaken to answer or explain them. The main research method applied was the multiple-case study, mainly because of the scarcity of the literature and also because of the search for practical solutions (in the field) rather than theoretical ones. The next chapter details the research methodology applied in this investigation.

Chapter 3. Research methodology

This chapter describes the research approach followed to conduct the inquiry. To this end it is divided in three parts. The first part describes the main criteria used to select the research methodology, namely the multiple case study method. The second part details how the research methodology was applied to the particular research problem. Finally, the framework used to analyse the data is described.

3.1. Selecting a research methodology

At the beginning of the research, literature on CE, NPD and PM was reviewed mindful of the goal of identifying topics for further research. It was sought to postulate, from these topics, original propositions or hypotheses to be proved or refuted through further empirical research. This so-called hypothetical-deductive research method was found to be common in the literature on the three approaches. However, publications on the relationship between them were so scarce and contradictory that it became difficult to find solid theoretical foundations from which to draw upon and therefore to formulate new hypotheses or propositions. This paucity and the contradictory explanations spawned the idea of developing research aimed at achieving a better understanding of this relationship.

Nevertheless, since a "better understanding" would not validate or refute any proposition or hypothesis, a crucial interrogation emerged: was "a better understanding" a valid outcome of a research project? Handfield and Melnyk (1998) argued that providing description and building relationships (explanation) are theory-building activities. Amundson (1998: 342) affirmed that "the purpose of theory is to define, establish, and explain relationships between concepts or constructs", and Pentland argues that "explanation is essential to theory and practice" (Pentland, 1999: 711). Finally, Strauss and Corbin (1998) defined theory or *theorising* as "the act of constructing from data an explanatory scheme that systematically integrates various concepts through statements of relationship".

Developing concepts, relationships, and explanations, instead of postulating propositions or hypotheses requires an *inductive* process, which differs substantially from a *deductive* process. Gill and Johnson (1997) explain the difference between induction and deduction using the learning cycle proposed by Kolb et al (1979) (Figure 3-1). According to the figure, learning might start with a concrete experience impacting upon individual's values, beliefs or attitudes. This impact may lead to observations or reflections that in turn may lead to casuistic explanations of the experience. This abstract explanation may be tested and, if proved true, it may yield a new or modified experience that would in turn lead to new observations. The learning cycle does not have a specific start: individuals might have preference for particular elements of the learning cycle. The deductive approach starts with the formation of an abstract explanation which has to be tested and then converted to a concrete experience (left side of Kolb's circle). The inductive approach starts with specific experiences that lead to observations and reflections and these in turn may converge upon a conceptual abstraction (right side of Kolb's circle).

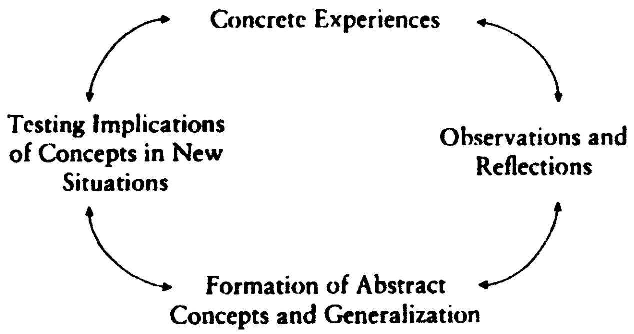

Figure 3-1. Kolb's experiential learning cycle (Kolb 1979).

In formal terms Gill and Johnson state that:

> A deductive research method entails the development of a conceptual and theoretical structure prior to its testing through empirical observation (page 28)... Induction involves moving from the 'plane' of observation of the empirical world to the construction of explanations and theories about what has been observed. (Gill and Johnson, 2002: 33)

According to these reflections, the research methodology was going to be based on the inductive approach rather than on a deductive one.

Inductive and deductive research can be developed using different methods, principles and rules. These can be classified as illustrated in the "onion" (Figure 3-2) proposed by Saunders et al (2003: 43). The "onion" represents an interesting conceptual schema because it associates the broad philosophical aspects that underpin the research activity (outer layers) with the more practical tools and techniques required in conducting the enquiry (inner layers). The elements appearing at the upper half of the onion correspond to positivism, and the elements at the lower half correspond to interpretativism. Elements appearing in the middle correspond to a more eclectic research perspective.

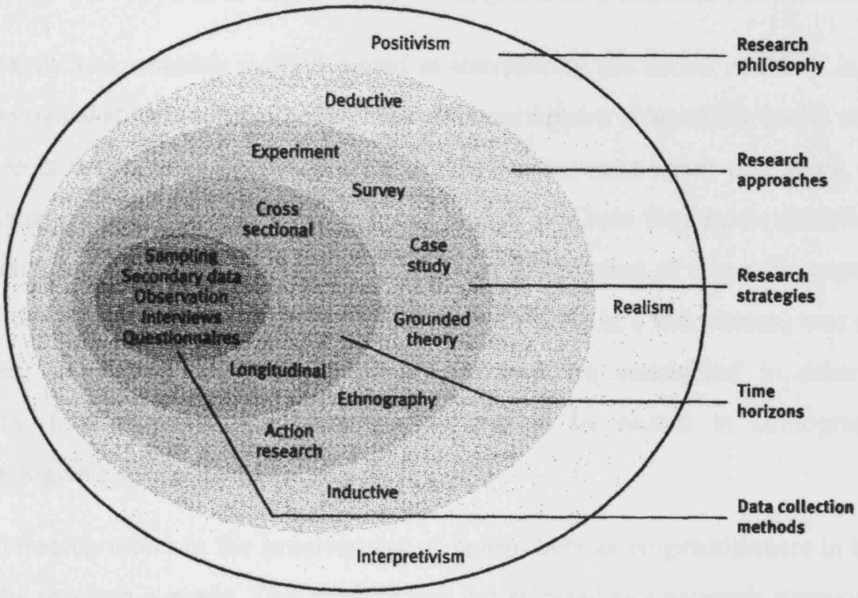

Figure 3-2. The research process ‘onion’ (Saunders et al. 2003)

After deciding the research approach (inductive), selecting the research methodology or “research strategy” (as it is dubbed in the “onion”) was a second and fundamental decision.

Experiments are tests under controlled conditions aimed at demonstrating the validity of a hypothesis. Surveys consist of gathering data from a statistical sample (considered to be representative of a whole) in such a way that the analysis of the data is co-related to demonstrate the validity of a hypothesis or proposition. In management research it is more common to apply surveys than experiments. In any case, these two methods were not selected because it was decided that hypotheses or propositions would not be formulated.

The case study "is a research strategy which focuses on understanding the dynamics present within single settings" (Eisenhardt, 1989: 534). Robson (2002) pointed out that this strategy involves an empirical investigation into its real life context using multiple sources of evidence.

Grounded theory is "how the discovery of theory from data, systematically obtained and analysed in social research, can be furthered (Glaser and Strauss, 1967: 1). Principles of this strategy were applied in this research to analyse data as explained in section 3.4.

Ethnography is a research method aimed at interpreting the social world. It is rooted in anthropological studies where the key feature is participant observation in the activities of the subjects under research. Mintzberg (1973) for instance spent one week observing what managers did, who they met and telephoned, and how they made decisions. Given the characteristics of the research goal, an intense observation of a specific organisational activity was not envisaged, therefore ethnography (taken in a strict sense) was discarded. However, some of the principles of ethnography are considered in other research strategies. Case research, for instance, is said to be rooted in ethnographic (and anthropological) studies (Voss et al, 2002).

Action research refers to the involvement of researchers as co-practitioners in the setting where the research is made. This method was not selected as a research strategy since the involvement in a particular setting was not considered.

As can be seen, some of the research strategies were discarded to conduct this investigation because of its deductive nature (experiments, surveys) or because the interaction between the research and the setting was not the desired method (ethnography, action research). Therefore, case research was selected as the most appropriate research methodology.

Yin (1993) emphasises that the selection of the research methodology should be based on the research question. He stated that the case study research strategy answers *how* and *why* questions; it does not require control over behavioural events (contrary to experiments for instance); and it focuses on contemporary events.

Meredith (1988) elicits three outstanding strengths of the case study approach based on the work of Benbasat et al. (1987: 370):

- The phenomenon can be studied in its natural setting and meaningful, relevant theory can be generated from the understanding gained through observing actual practice;
- the case method allows the much more meaningful question of *why*, rather than just *what* and *how*, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon; and
- the case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood.

Since the case study methodology also helps in answering *what* questions (description) or in testing theory (Eisenhardt, 1989; Yin, 1994), the choice of the methodology was justified as it covered the nature most of the research questions.

3.2. Designing the research method

After selecting the research methodology (Case Study), the next step was the planning of the necessary steps to apply it, in other words, the design of the research method.

At the outset it was crucial to decide whether to start with preliminary conceptual constructs stemming from the literature or experience, or to ignore the literature and to start without any pre-conceived idea. There are cogent arguments substantiating each approach. For instance, Eisenhardt, Miles and Huberman advocate for preliminary constructs:

> *A priori* specification of constructs can help to shape the initial design of theory building research (Eisenhardt, 1989: 536).

> Doing the exercise of building a conceptual framework prior to the research, forces one to be selective at least at the outset (Miles and Huberman, 1994: 18).

Yin (1994: 106) states that comparing predicted patterns with empirically based patterns strengthens the internal validity of the case study. He then proposes an iterative comparison and revision of the predicted pattern with the findings of the case studies. Following this approach, Harris and Sutton (1986), constructed rough frameworks at the beginning and subsequently compared them with new evidence from the field study.

Others researchers recommend "to ignore literally all the literature to prevent that the emergence of categories could be contaminated by concepts more suited to different areas" (Glasser and Strauss 1967: 37). Burgelman (1983) adopted this strategy in his award winning doctoral dissertation and started without pre-conceived frameworks.

Little has been written to explain how and why a relationship between CE, NPD and PM helps to improve product development. This was certainly a convincing argument for starting from scratch. However, during the literature review, conceptual constructs were developed to try to understand some propositions made by different authors, and these constructs could have been used to design the research method (see examples of these preliminary constructs in Appendix A).

It was finally decided to use the preliminary constructs to prepare the field research. First, the initial constructs would be used "to be selective". That is, they would help to design a more focused case study protocol. Second, it was believed that preliminary constructs would save time in conducting the case studies. However, as "investigators are cautioned not to postulate very subtle patterns" (Yin, 1994: 110); the preliminary constructs were not used as a definitive evidence of internal validity.

The next step was the definition of the unit of analysis. Precision is required to focus the efforts on collecting and analysing data (Miles and Huberman, 1994; Yin, 1994). Since the most important issue in this research was to investigate how three approaches were related and what the benefits on product development were, the unit of analysis would be the process to develop new products; including implementation, operation and improvement. The unit of analysis helped to clarify what should and should not be analysed.

The setting refers to the organisation, agency or community in which the case study is conducted (Kumar, 1999). Since the unit of analysis was the process to develop new products, the settings had to be organisations developing new products. The necessary condition was that these organisations were applying CE, NPD, and PM, or at least two of the three approaches.

Personnel within the company would decide whether they were applying these approaches as it could have been cumbersome to develop a previous assessment. To this end, the access letter (appendix B) was designed to describe the requirements for the case.

During the first contact, questions were asked regarding the level of implementation of each approach, the answers were taken *bona fide* and verified once in the field.

The next question to be answered was how many cases. In case study research the samples tend to be purposive (Miles and Huberman, 1994) and small compared with the number of samples utilised in surveys. According to the literature reviewed, the number of cases ranged from one (Nightingale, 2000) to 30 (Pagell and LePine, 2002). Because of the limitations of time and resources and following the suggestion that "a number between 4 and 10 cases usually works well" (Eisenhardt, 1989: 545), it was decided to attempt between four and six case studies. Since more than one case was developed, the methodology followed in this research can also be named "multiple-case study research" (Meredith, 1988: 443).

The process to select the companies was simple. The researcher asked experts in the field to recommend companies. The next step was to send access letters to the recommended representatives in the companies. Four out of seven companies accepted the invitation. This method has been named "by convenience" (Saunders et al, 2003; Milles and Huberman, 1994) and although valid, it is considered that it may "compromise the representativeness of the sample" (Saunders et al, 2003: 171).

The level of analysis is important for a better interpretation of the results and three levels are frequently considered in organisational studies: individual, sub-unit, and organisational (Bryman, 1989). Pentland (1999: 414) suggests that the focal actor(s) determines the level of analysis and they could be individuals, groups, projects or whole organisations. Therefore, as the development of new products is (or must be) cross-functional and cut across several hierarchical levels, the level of analysis was set at an organisational level or, as Langley (1999) affirmed, multiple levels of analysis were going to be considered.

Next, the position of the interviewees was appointed. Company structures vary from one to another; then, generic roles along the development of new products were envisaged:

- The manager to whom all functional managers involved in the process report.
- Functional managers or divisional heads.
- The leader of the implementation effort of CE, NPD, or PM.

- The project or program manager and / or the product manager.
- Specialist working in the teams or in the functional departments.

Table 3-1 presents a list of the persons interviewed according to their generic role or position in the company. Every case study description (Ch. 4) presents a list of the specific roles that the interviewees played in each company. Unfortunately, managers to whom all functional managers involved in the process report could not be interviewed (General or Divisions Directors). According to the companies' representatives, they did not have time for interviews. The implications are discussed in Ch. 6. In total, 37 persons from the four settings or case studies were interviewed, taking on average 2 hours each.

Table 3-1. Generic role or position of the interviewees

Role/position (Generic)	Number
The manager to whom all functional managers involved in the process report.	None
Functional managers or division heads.	6
Leaders of the implementation effort of CE, NPD, or PM.	10
Project or program manager and / or the product manager.	16
Specialist working in the teams or in the functional departments	5

Yin (1994) describes six sources of evidence: documentation, archival records, interviews, direct observations, participant observation, and physical artefacts. Out of them, four methods were the most important in this research: documentation, archival records, direct observation, and interviews. Documentation, on paper and on-line, included the methodology to develop new products, organisational charts, technical procedures, and product catalogues.

Interviews were mainly orientated to investigate why and how the initiatives had been implemented, operated and improved. If any of the approaches had not been implemented, the interviewees were asked about the main reasons for that decision. Although observation was not the principal source of information, observing reactions and voice tone during the interviews gave additional evidence, for example, when people hesitated in answering.

The next step was the preparation of the plan to collect data. The empirical gathering of data requires instruments:

> Instrumentation may mean little more than some shorthand devices for observing and recording events . . . (whereby) some technical choices must be made: will notes be taken? Of what sort? Will the transaction be tape- recorded? Listened to afterwards? Transcribed? How will notes be written up? (Miles and Huberman, 1994: 35).

To this end, Yin recommends the use of a case study protocol:

> A case study protocol is more than an instrument. The protocol contains the instrument but also contains the procedures and general rules that should be followed in using the instrument. (Yin, 1994: 63)

Hence, a Case Study Protocol (CSP) was prepared to perform the fieldwork. In the preparation of the CSP, the level of detail should be considered first (Miles and Huberman, 1994: 36). As an exploratory approach the instrument should be generic enough to be used as a guide and not as a prescriptive protocol. Nevertheless, it was decided to develop a more detailed instrument to prevent omissions due to the lack of experience in developing case study research. This decision proved to be correct because, although many details were not necessary, the preparation of the CSP helped to gain confidence before going to the field. Appendix C presents the CSP as it was originally designed. It outlines the plan to conduct the fieldwork, the questionnaire and the likely outline of the analytical report.

The key component of the CSP was the questionnaire. This was designed to associate the abstract theoretical questions with simple operational questions to be posed to the interviewees. To this end, the preliminary conceptual framework helped since it contained some explanations that should be verified or refuted. The questionnaire was used as a guide and, given the exploratory nature of this research, not all of the questions were asked. Some questions were adapted to the company's background and specific situations. In general, the most important questions were:

- How does your company develop new products?
- What is your role, what are your activities during the development of new products?
- When does your work start/finish regarding the development of new products?

- What are your main tools and techniques?
- What are the main problems around new product development?
- How do you plan and control the resources?
- According to you understanding, what is PM/NPD/CE?
- Is your company applying CE, NPD, PM? How? Why? If not, why not?
- How do you manage the relationship between CE, NPD, and PM to develop new products? Were you concerned about this relationship?

3.3. Framework to analyse data

The application of a case study or any inductive method in general, entails two main difficulties. First, the volume of data gathered in the field might be overwhelming. The data was collected in the form of field notes, transcription of tape recordings, company documents, and summaries or write-ups. The 37 interviews were tape- recorded and transcribed in separate files of about 6 pages each. Thus, it was necessary to find a method to store, handle and synthesise all this information; otherwise, there was a danger of "death by data asphyxiation" (Pettigrew, 1988).

Second, "using extended text, a researcher may find it easy to jump to hasty, partial, unfounded conclusions" (Miles and Huberman, 1994: 11). Therefore, it was necessary to demonstrate how the conceptual propositions of this thesis had been constructed from empirical data.

In solving these two issues, a strategy to analyse the data and present the results consistently (and convincingly) was applied. This strategy was based on two research methodologies: grounded theory (GT) and qualitative research (QR).

GT is *theory* derived from data as opposed to theory tested with data as in a deductive approach. It is about "how the discovery of theory from data, systematically obtained and analysed in social research, can be furthered" (Glaser and Strauss, 1967: 1). GT should attempt to:

> Generate theory that works – provide us with relevant predictions, explanations, interpretations and applications...Theory that can meet these requirements must fit the situation being researched, and work when put into use. By 'fit' we mean that the categories must be readily (not forcibly) applicable to and indicated by the data under study; by 'work' we mean that they must be meaningfully relevant to and be able to explain the behaviour under study. (Glaser and Strauss, 1967: 3)

Grounded theory involves two main methodological steps: theoretical sampling and constant comparison (Gephart, 2004; Suddaby, 2006). Theoretical sampling is a process in which "emergent insights direct selections and inclusion of the "next" information or slice of data" (Gephart, 2004:459). Constant comparison or the constant comparative method (Strauss and Corbin, 1988) is a method through which "data are collected and analyzed simultaneously" (Suddaby, 2006: 634).

The principles of the "constant comparison" were applied during the research. They helped to elaborate concepts, categories, properties and dimensions as well as conceptual propositions. The most important principles taken from the constant comparative method (Strauss and Corbin, 1988) were:

- Build conceptual categories from accurate evidence bearing in mind that facts are temporal and conceptual categories are permanent.
- Compare similar and different facts to generate properties of the categories, or sub-categories, and their associated dimensions that in turn increase the categories' generality and explanatory power.
- Specify concepts in the form of unit of analysis for comparative purposes. Units of analysis in this case refer to words, sentences or paragraphs expressed by the interviewees.
- Generate theory by formulating conceptual categories and their properties.

- Verify and check the theory that is being generated as the data pours in.

Concepts like *meta-concurrency* or *aligning-process schemas* (see section 5.2, Figure 5-4, and sections 5.6.1, figure 5-7)and their categories and properties were empirically induced in this research by using these principles.

The "theoretical sampling" process was not rigorously applied. The field research was not planned to gather and analyse data from the first case study and based on the findings to decide and plan the data to be gathered in the next case study. However, the data gathered and analysed in the first case study helped to refine, add or delete questions for the next case (although the data to be gathered would be essentially the same).

Qualitative research (QR) is, like grounded theory, a concept strongly linked to inductive studies. Moreover, it would be difficult to ascertain what the difference between GT and QR is. For instance, Strauss and Corbin denote QR as "any type of research that produces findings not arrived by statistical procedures or other means of quantification" (Strauss and Corbin, 1998: 10). Both methods have extended application in ethnography. Note for instance the ethnographic connotation of the following definition of QR:

> Qualitative research is a particular tradition in social science that fundamentally depends on watching people in their own territory and interacting with them in their own language, on their own terms. (Kirk and Miller, 1986: 9)

In explaining qualitative research, authors frequently compare it with quantitative research. The dialectic involved in analysing these two terms has its roots in positivism (related to quantitative research) and interpretativism (related to qualitative research). Kirk and Miller quoted:

> Technically, a qualitative observation identifies the presence or absence of something in contrast to quantitative observation, which involves measuring the degree to which some feature is present. (Kirk and Miller, 1986: 9)

Miles and Huberman (1994: 12) proposed a model to analyse qualitative data (Figure 3-3) and describe a large number of techniques that can be applied at each step of the model. This model was useful in building synthetic tables and figures.

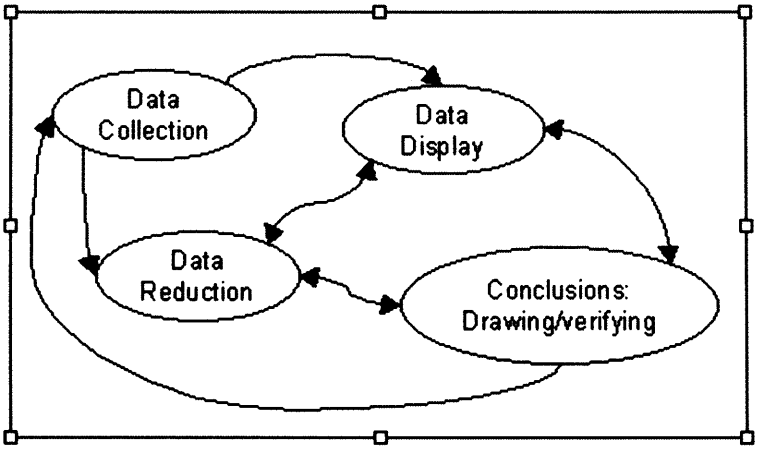

Figure 3-3. Components of data analysis (Miles and Huberman, 1994: 12)

Computational aids to handle the high volume of information were also used. A software called QSR N6™ (formerly NUD*IST)[5] was used to store, code, retrieve, cluster and analyse qualitative data. Mind Manager™[6], a visual tool to brainstorm and relate ideas, was used to connect conceptual ideas and concepts.

In brief, the steps followed to analyse the data are described as follows:

Code data and create concepts.

The interview transcripts were transferred to N6 software. In this software the texts were analysed and coded selecting one unit of analysis; either words, sentences or paragraphs. At the beginning, sentences were selected as the unit of analysis, but many sentences did not describe the whole idea expressed by the informant, thus it was decided to analyse by paragraphs. Each paragraph was then coded under a concept that represented the idea. Following the "comparative analysis" principles, some of these concepts were borrowed from the literature (pre-established theory) or from the preliminary constructs (Appendix A), for instance, "early involvement". Appendix D shows an example of this process.

Cluster data.

During and after coding, similar conceptual codes were clustered. The result was a tree-type structure of codes describing ideas. Not all the codes fit into the structure and they

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[5] QSR N6 Release 6.0 is a trademark of QSR International Pty. Ltd 1991-2000.

[6] Mind Manager Standard edition 4.0 is a trademark of Mindjet LLC 1994-200.

were catalogued as "free codes" in N6. Appendix D shows an example of a tree-type structure of conceptual codes.

Memoing.

Memos are "the researcher's record of analysis, thoughts, interpretations, questions, and directions for further data collections" (Strauss and Corbin, 1998: 110). Hence, "memoing", the activity of doing memos, is an intellectual activity to reflect over potential discoveries during the hard work of coding. In the search of rich knowledge, memos are metaphorically like diamonds in the rough; after polishing they could prove valuable or valueless. With the aid of N6, memos were attached to coded text. Appendix D shows an example of a memo written during the field study.

Describe the case.

Case study description is a recommended strategy to analyse data (Yin, 1994). To this end, Eisenhardt recommends to elaborate write-ups offering a "simply pure description" because they help to cope early in the analysis with the impressive amount of data (Eisenhardt, 1989: 540). Following these concepts, every case was described and presented in chapter 4.

Develop cross-case patterns.

Herein started the task of eliciting common and different patterns from the four cases. The main challenge was to distinguish what was important and what was not using the concepts already created. As a result of the intense effort of the previous steps, many of the most important concepts resided obsessively in the researcher's mind, therefore, the concepts with the most explanatory power confirmed or generated new theory in form of propositions or conceptual frameworks (figures, structures, models). Chapter 5 presents the corresponding cross-case analysis.

Analyse concepts.

This exercise is a sort of step-back because every concept developed in the previous step had to be cross-analysed between the cases. The utilisation of Mind Manager helped to map all the possible connotations and relationships of some important concepts (see Appendix D for an example).

The whole process was recursive. For instance, the elaboration of memos sometimes led to a re-structuring of the coded text. Likewise, the research goal was always present in the researcher's mind to avoid data "asphyxiation" or biased conjectures.

The incursion in the field, the data gathering, and the analysis was planned in such a manner that:

- Time was reserved to make notes, pre-analyses and adjustments between one visit to the field and the other. (Milles and Huberman 1994)
- The possibility existed to return to the field to collect missing data after having made the analysis. (Yin, 1994)

Despite the plans, the fieldwork turned out to be dependent on the informants' willingness and possibilities to be interviewed. On certain occasions, there were long waiting times between one interview and the other, whereas in other occasions multiple interviews had to be achieved in one journey. Likewise, during certain periods of time three case studies were developed in parallel because of the companies' timelines. These constraints did not greatly affect the results, but they possibly extended the duration of the research.

One fundamental research query had to be answered at the end of step six (analyse concepts): whether more than four cases would be necessary. The main goal of the research was the creation of theoretical concepts or categories and its properties with the most explanatory power. This explanatory power is achieved when the concepts and its properties are saturated, where saturation means "that no additional data are being found to develop properties of the categories" (Glaser and Strauss 1967: 61). Based on this argument, it was decided that there was no need for more case studies as the concepts generated were considered reasonably saturated.

In sum, this inductive research was based on the case study methodology (Eisenhardt, 1989; Yin, 1994). The data analysis was supported by the "constant comparative " method (Staruss and Corbin, 1988), which is based on grounded theory (Glaser and Strauss, 1967), and by qualitative research tools (Miles and Huberman, 1994).

However, "no analysis strategy will produce theory without an uncodifiable creative lap, however small" (Langley, 1999: 691). The systematic process of coding and structuring produced one or many cluster-type diagrams, tables, maps and the like. These constructs, however valuable, doubtfully represented theory or "good theory" (Whetten, 1989). It was sought pattern recognition and "human, not electronic, brains are most capable of achieving those goals" (Mintzberg, 1979: 588).

In some cases the researcher's intuition (assumptions, judgment, and past experiences) and the iterative process of reviewing the literature and the case evidence (Lewis, 1998) helped to shape final concepts and propositions. As Langley (1999: 708) sustained, the theory building process involved not only induction, but deduction and "inspiration" which was stimulated by empirical research, by reading, and by mental exercises.

The iterative triangulation between empirical evidence, literature review and intuition provided a *quasi-systematic* method to spur creativity in the search for connections. This method proves to be useful when existing literature contains "contradictory theory and evidence and spans theoretical perspectives and academic disciplines" (Lewis, 1998: 458).

Chapter 4 Case studies

Introduction

> Within case analysis typically involves detailed case study write-ups for each site. These write-ups are often simply pure descriptions, but they are central to the generation of insight because they help researchers to cope early in the analysis process with the often enormous volume of data. (Eisenhardt, 1989: 540).

The main goal of this chapter is to provide description of the case studies. Description is presented as pure as possible trying to avoid analysis or to induce conjectures so that the reader can formulate his or her own assumptions and conjectures based mainly on the emerging data.

However, "theory building seems to require rich description, the richness that comes from anecdote" (Mintzberg, 1979: 587). Therefore, many quotes made by the practitioners have been literally transcribed and some personal comments added. The intention was to "catch the reader in the description, so that he or she feels vicariously that he or she is in the field" (Glaser and Strauss, 1967: 230). In doing this it was attempted to develop more interesting write-ups to the reader than pure and perhaps *dry* reports.

Each case description is structured as follows. First, the company and its products are described to provide context. After that, the NPD processes as well as the organisation for the development is explained. Then, details are given about how CE, NPD, and PM are applied in the company. Finally, the empirical data regarding the relationship between the approaches is presented. Each case description ends with a list of people interviewed and a list of tools and techniques applied to develop new products.

4.1 Telecommunications company

4.1.1 Company and products

The company operated within the telecommunications sector. It had undergone a vertiginous growth since its foundation approximately 20 years ago. Having started with approximately fifty employees ten years ago, the company employed more than sixty thousand at the time the case was developed, approximately 9,000 of which were part of the business unit studied. The impressive expansion was not only due to an increased market demand, but was also explained by acquisitions and joint ventures world-wide; movements that inevitably led to the continual re-structuring of the organisation and its processes.

The company provided voice, text and image transmission services. To give an idea of the extended variety of products that the company could potentially develop, one executive commented:

> Everything you can imagine regarding communication, from the acquisition of one drink from an automatic machine using electronic money, up to a lorry fleet totally equipped and monitored remotely.

Besides high product diversity, the projects to develop new products varied considerably in size and cost. Big projects included the development of new infrastructure and data transmission technology, software development, and marketing campaigns. By contrast, small projects were developed to update or add features to products currently on the market. The organisation managed a mix of around 80 new products of different size at the same time. As a consequence, the lead-time to develop new products also varied considerably. The elapsed time between project definition and product launch ranged from 40 days to more than 6 months from one development to another.

The company used to investigate customer needs to breed ideas for new products. However, this was not the only channel; innovation could spark from anyone in the company. Projects were also "me too" driven, that is, they were developed to launch products or services already or about to be offered by competitors. In any case, time to develop was vital because of the highly competitive sector.

This ever-changing milieu impacted on the way the company was managed as well as on the behaviour and attitude of its employees. "Change" and "unstructured" were two of the most common words mentioned by the interviewees to describe the company's dynamic environment. So fast was the speed of change, that the board of executives trained and allocated "strategic change people" at corporate level and across the company to help in confronting the next impending organisational upheaval.

4.1.2 New Product Development

NPD process

The process to develop new products comprised two major phases: "select" and "delivery". Each phase was divided into three stages (Figure 4-1). In the "select" phase the feasibility of every new idea was evaluated and authorised or rejected. In the "delivery" phase the approved ideas were designed, developed, tested, and launched to market. After finishing each step, an executive committee joined together in meetings to review the consistency between the stream of products being developed and the business goals. These reviews are represented as milestones in Figure 4-1. The following is a brief description of every stage transcribed as it was written in internal documents.

Stage 1. Manage New Ideas. In this step the concepts potentially to be transformed into new products are investigated further. The product manager interacts with the chief designer or group chief designer to capture and clarify the user requirements.

Stage 2. Test Concept Feasibility. This step comprises the financial and technical feasibility studies. Basically the product managers aided by business analysts make the financial study, whilst the designers make the technical one. The project manager is then engaged to start configuring a plan for the feasibility study as well as for the next stage.

Stage 3. Develop proposals. The next step consists of a refinement of the technical and financial studies made in stage 2. The designers develop the corresponding technical specification and requests for proposals, considering the estimates made by internal and external specialists likely to be engaged in the ensuing development and testing steps. Project plans are also reviewed and refined by the project manager in co-ordination with designers and future developers.

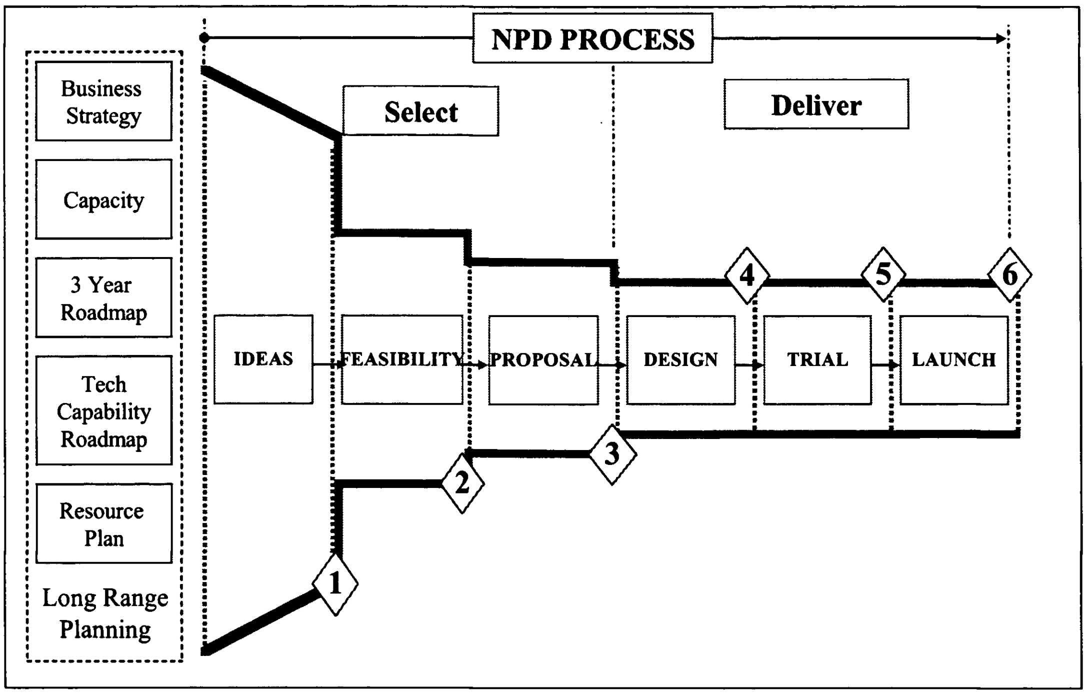

Figure 4-1. The New Product Development process

Stage 4. Design, develop and test. Specialists in technology/domain areas or external suppliers carry out detailed designs and develop the product. Project managers from the NPD group co-ordinate the activities of different groups and keep close contact with the product manager to assure customer requirements are fulfilled.

Stage 5. Product trials. Trials are made across the corresponding business units to test the entire product. Included in this stage is the acceptance of customers and internal stakeholders, as well as the training and launch plan strategy.

Stage 6. Product launch, project closure and ongoing monitoring. The decision to launch the product into the market along with the review process for the project gets underway. This stage is indicative of the project hand over, from the new product development team to the Core Product team and Operations. End project reports, lessons-learned reports and celebration of success, as well as the review of key performance indicators (KPIs), are part of this stage.

The process was in essence a "stage-gate process" similar to that proposed by Cooper (2001). It also incorporated the *funnel* concept which has been proposed by, amongst others, Wheelwright and Clark (1992). The *funnel* is schematically illustrated in Figure

4-1 and represents a screening process to discard or retain those ideas that were not aligned with the business strategy.

Organisation for the development

The organisational structure of the company is portrayed in Figure 4-2. Basically, three organisational units planned and executed the projects to develop new products: Product Management, Product Development, and Technology Domains. The rest of the organisational units were in charge of the production, sales, and support of the products currently on the market. An "NPD Review Body" composed of all the functional heads (second and third level) had the principal responsibility for new product development decisions.

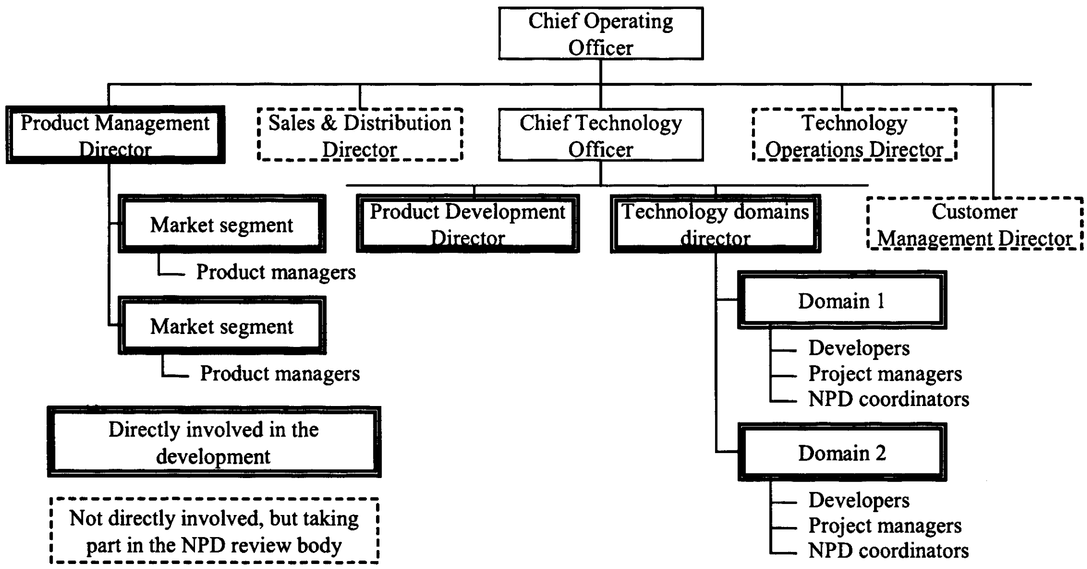

Figure 4-2. Organisation for the development

The Product Management unit was responsible for product performance in the market and for introducing new products to market. The managing director of this unit was responsible for the product-portfolio strategy. Product managers from this department researched customer needs or captured new ideas. They then engaged the Product Development staff to develop the commercial and technical proposals.

The Product Development unit (Figure 4-3) played the principal role in transforming new ideas into products to launch. Teams called "cells" integrated by business analysts, designers, program and project managers, led by group chief designers, performed the "select" phase in close relationship with the product manager. Designers transformed the product manager's requirements into basic specifications and developed the technical proposals. The economic proposals were prepared simultaneously by product managers, aided by the analysts. Program and project managers co-ordinated meetings, developed plans, and estimated resources to develop the products. Once a proposal was accepted (milestone 3), the program and project managers of the cell co-ordinated the activities during the next "deliver" phase. "Executives" in the Product Development organisation were in charge of product platforms. The Senior Program Manager and his staff supported and improved the NPD process as is explained in the next section.

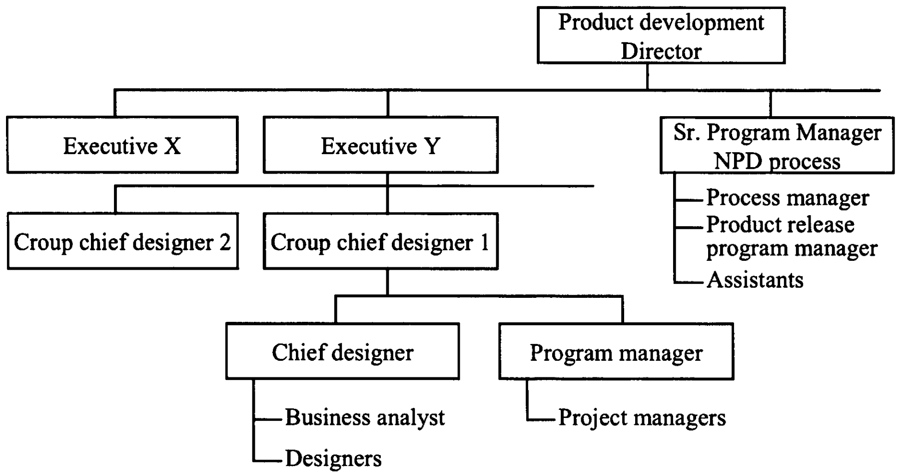

Figure 4-3. Organisational structure of the Product Development Direction.

During the "design" stage different technology-domain groups or suppliers transformed the high level designs into detailed designs and carried out the development of the products. During the "trial" and "launch" stages, technology-operations units carried out corresponding tests whereas Sales and Distribution and Customer Management were responsible for the product introduction to the final customers. Figure 4-4 displays the participation of the different roles and groups along the NPD process.

Engagement and disengagement of program managers

Program managers were normally engaged in the process to develop new products at the end of the "ideas" stage or at the beginning of the "feasibility" stage. Although the level of interaction was highly technical during these stages, the program manager was engaged to co-ordinate meetings and to delineate the plans for subsequent stages. These activities enabled program managers to have an early involvement in the process, thus facilitating an integrative responsibility in the program or project when authorised.

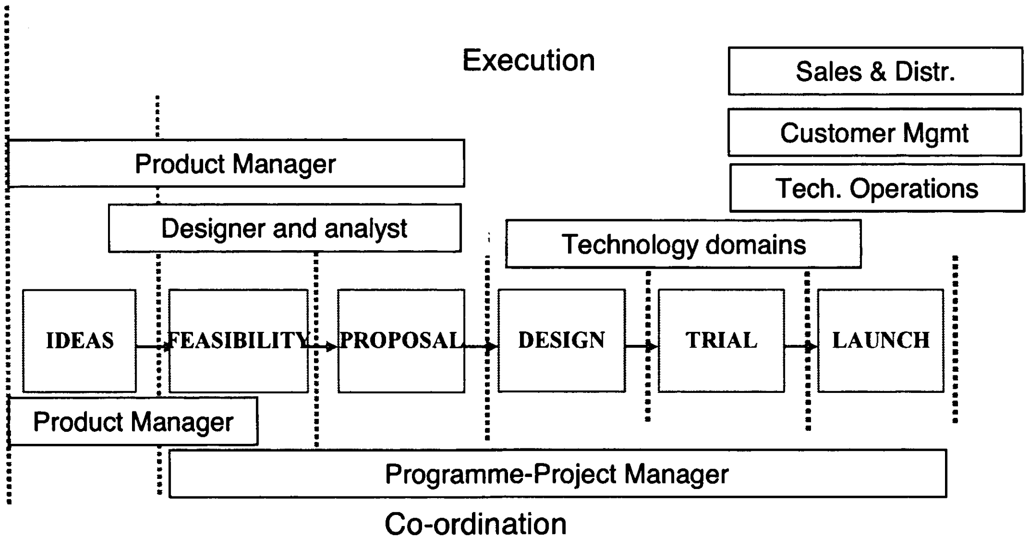

Figure 4-4. Coordination and execution of the NPD process.

At the other end of the development, program and project managers handed over the project approximately 90 days after the product was launched into market. At that point in time, the project team met with operations people to review the last status of the product (milestone 6).

NPD Implementation and benefits

The NPD process had been implemented approximately 1.5 years ago. Before that, the company was operating through independent business units where a corporate project management group was in charge of developing new products across the units. A reorganisation then took place and these units were grouped under one single unit. As a result, every business unit changed to functional areas and the project management function was "relegated to co-ordinate some technical efforts".

Executives felt that the new organisation required a cross-functional process to develop new products, and a consultant was hired to delineate a "high level" (not detailed) New Product Development process. The goal of the NPD process was "to develop the best products and services to support the business strategy".

A board of directors from all areas involved in the development was formed to take strategic decisions on the NPD process design and implementation. After documenting the NPD process at a high level, the consultant led internal workshops with people from the different functional units to detail the process. After that, training sessions were launched to disseminate the new approach. The persons participating in these sessions were all of the people from the Product Development group, product managers from the Product Management group, project managers and NPD co-ordinators from the Technology domain areas. Following these sessions, the new process had to be applied to every new project.

Interviewees were asked about the benefits of the NPD process and the main comments are presented in Table 4.1. In general the opinions were positive and consistent with the purpose of the new process.

Table 4.1. Benefits of the NPD process.

It is good; it is a gate keeping process. Making sure that people do it right. It is a high check really.
The NPD process is very good in picking up sort of visibility concept ideas all away through the delivery.
The main thing we've achieved which I guess is a part of the original process was on reliability, getting things to market when we want to get them to market, we've cut the time to market.
The problem that we were facing was not how we would manage a project but how we would ensure that the project can be managed across the company as it is cross functional and that was the issue and the process was the way to solve that.

However, there were still some issues concerning the refinement of the process, the improvement of cross-functionality and a clearer definition of roles and responsibilities (Table 4.2).

Table 4.2. Concerning issues regarding the NPD process implementation.

We can refine it and start to get more buy-in from the people in the domains, we can start re-sourcing the domains appropriately to do the developments that we want to do.
The key problem area at the moment is the front-end engagement. We have to involve the various areas that need to have an input into the design and development as well as to foster joint decision making around which products we do and how we take them forward.
We have problems with people not actually understanding what their roles are in the process, so we spend a lot of time with people to improve their understanding in the process.
I think there are problems in the definition of roles and responsibilities.

These concerning issues could be considered part of the learning process. It should be taken into account that the implementation process started two years ago. NPD process methodologies are estimated to take between five and six years to reach considerable maturity level and to achieve sustainable gains (O'Connor, 1994).

Support and resource management

The NPD process was supported and improved by a team reporting directly to the Product Development Director. A senior program manager, one process manager, one product release program manager and the NPD co-ordinators of different Technology domain groups were part of the team (see Figure 4-3).

The responsibilities of the NPD process manager included the maintenance and improvement of the NPD process methodology, as well as the co-ordination of the NPD review body meetings. He was also responsible for the implementation and operation of a software tool called Accolade®. Through this Web-based software, all licensed users had input and access to the NPD process methodology and to the documents issued during the development of every product (assisted workflow).

The NPD co-ordinators belonged to the different technology domain groups. They served as a contact point with the Product Development group to facilitate communication, assist in decision making and ensure that issues were quickly identified and addressed.

The product release program manager was responsible for consolidating the release programs of every individual product after the project authorisation (Milestone 3). He made resource analyses as needed to adjust every individual release program under two main criteria: the availability of the resources and the strategic priorities set by the board of directors. To develop the task, he gathered preliminary schedules coming from every domain participating in a particular development. Then, he integrated each particular schedule into one general schedule and checked the resource availability and the business priorities. Finally, he closed the loop by feeding the reviewed schedules back to the corresponding domain areas for authorisation.

This task of integrating the schedule and balancing the resources was iterative and performed using MS Project™ and spreadsheets. The product-release program manager collected and distributed all information by mail or hard copy; in other words, the company had the opportunity to improve the process by using on-line information systems.

Whilst during the "deliver" phase the product release program manager was responsible for resource balancing, there was not a single point of responsibility for this task during the "select" phase. Before project authorisation, the group chief designers were responsible for the assignment of resources from the Product Development cell. The head of the Product Management division was responsible for the assignment of product managers.

Managers admitted that this lack of a centralised function could have been causing an inefficient use of resources. However, one chief designer mentioned that "too much control over these early stages is difficult to achieve because there is a lot of uncertainty around the development of new ideas". In pursuing flexibility without loosing control, managers planned and controlled the resources in this phase on a stage-by-stage basis. Additionally, they argued that the use of resources at the "select" phase was significantly less than at the "delivery" phase. In other words, the need for flexibility at the early stages could have outweighed the benefits of a better control of resources. In any case, the company was planning the introduction of Oracle Project Accounting™ to improve control without necessarily loosing flexibility.

4.1.3 Project Management

The Eden project and PRINCE 2

Approximately six months after launching the NPD process, the company undertook an initiative called Eden aimed at promoting and standardising project management practices across the organisation. The Eden initiative was steered by a board of directors and executed by a task force group co-ordinated by a senior program manager.

The scope of Eden included the selection and implementation of a project management methodology, the certification of project management knowledge and skills and the establishment of the project management career development.

Regarding the selection and implementation of a PM methodology, the task force group decided to implement PRINCE 2 ("Projects in Controlled Environments", version 2[1]) (see also chapter 2). PRINCE 2 was implemented in all organisational units but the level of detail was different depending on whether the activities were mainly project, or ongoing orientated. For instance, Customer Services, whose activities were mainly ongoing orientated, should apply fewer templates than Technology/domain or Product Development, whose activities were primarily organised on a project by project basis.

As to the level of knowledge and skills of the project and program managers, the company decided to adopt the examination mechanisms established by the Association for Project Management (APM) in the UK.

With regard to career path, the company planned that any person involved in projects should be involved in training and getting promotions based on the following levels:

- Project Manager 1, 2, 3 and Senior Project Manager
- Program Manager and Senior Program Manager
- Project/Program Support 1,2,3 and Senior Project/Program Support
- Project Management training for executives and team members

Functional Directors assigned the necessary funds and resources to implement the initiative, therefore, the pace to implement Eden varied from one Direction to another depending on their priorities. Interestingly, the level of advance in implementing Eden in the two main divisions in charge of new products was substantially different. Whereas the Product Development group showed little involvement, Technology/domain groups adopted the initiative very fast. Moreover, the persons interviewed from Technology/domain complained that project managers from Product Development were not using PRINCE 2, but the NPD process methodology. The likely reasons for this concerning issue will be explained later.

Programs and projects; program and project managers

In essence, the difference between a program and a project was that programs consisted in delivering several interrelated products being developed as individual projects. One program manager made a distinction of the program in the following words: "a program is a full proposition rather than individual products". Correspondingly, programs were assigned to a program manager and projects to project managers.

A pool of program and project managers was under the functional command of the group chief designer. Thus, at the "ideas" stage, a program manager was assigned to assist the product manager in the co-ordination of the proposal. Depending on the magnitude of the program being created, one or more project managers were assigned by the program manager to co-ordinate the different individual projects of the program.

The importance of the programs required program managers to develop a business vision and to work as contact points with other functions, including externals. They relied on project managers for the successful development of individual projects. Thus, program managers had to develop multi-project management skills such as project prioritisation, program visibility, and resource allocation. In all, the Pm execution perspective was apparently being enacted by project managers and the PgM broader perspective by program managers. Characteristics of the MP perspective were not clearly observed.

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[1] A PRINCE 2 conceptual schema can be seen in the "Literature Review" chapter.

4.1.4 Concurrent Engineering

The senior program manager in charge of the NPD process commented that the company had not launched an initiative to implement CE. However, he believed that they were practising it, "depending on what you understand by concurrent engineering". To him, there were different forms of defining concurrent engineering and most likely, each person interviewed would have a different perspective or not even be acquainted with CE at all.

Effectively, most managers and specialists interviewed (11 out of 14) had not heard of the term. The three managers who acknowledged the term were asked to define CE and whether it was applied in the company. Table 4.3 shows that their understandings were not quite homogeneous, but they mentioned CE characteristics which appeared in the literature, like simultaneity (understood as synonymous of concurrency), design and development across countries, and co-location (see Ch. 2).

Table 4.3 Different understandings of CE

We engaged consultants and we did a big package of work in a Technology domain area around how the things move through, what are the process we work, how we do some simultaneous and concurrent. But it has not been a corporate view we are now doing CE, in some of the technology areas there are more games to be made. The term, I don't think there is universal definition that is broadly understood, probably more understood in the technology area.
I don't believe that we have really got the need for that, or yes we have got the need for it but I also don't believe that we have ever really thought about it properly. I guess my past is probably from development, whereby you have done a piece of the product in one country, then you could easily do another bit in another country and pass that design file over to somebody else. That is really the only way I have personally come into contact with Concurrent Engineering techniques
Yeah, I've heard about it, when I've worked we used a form of CE. We had a project team in a big office, manufacturing engineering, design engineering, marketers and so on, and that shortened the lead-time dramatically to get things to market. No, we haven't implemented concurrent engineering here. We don't have among other things, a proper functional approach to developing products, which is one of the fundamentals in concurrent engineering

Despite the absence of an initiative to implement CE and the lack of knowledge about the term, an important finding was that CE practices were being applied in the company. The researcher identified these practices when people explained how they developed new products. At the end of this case study description, the main tools and techniques used for the design function are listed. In what follows, the main CE practices observed are presented seriatim.

Early involvement in design

Design engineers and developers ("downstream" specialists) from Technology domain areas were involved early on by "high-level" or conceptual designers ("upstream" specialists) from the Product development division. Firstly, they met frequently to discuss the feasibility of the concepts being created. Secondly, based on the information released by conceptual designers, design engineers estimated the necessary costs and labour to develop the concept. Finally, design engineers had to sign-off the high-level or conceptual designs before being released and authorised by managers and executives. This condition guaranteed the "doability" of the concept.

Commercial and operations departments were also aware of the early ideas by means of frequent meetings and memos called "press releases". In addition, the milestone review meetings involved Directors from many disciplines that met specifically to review the status of the products being developed. All these activities to fostering participation early on are illustrated in Figure 4-5.

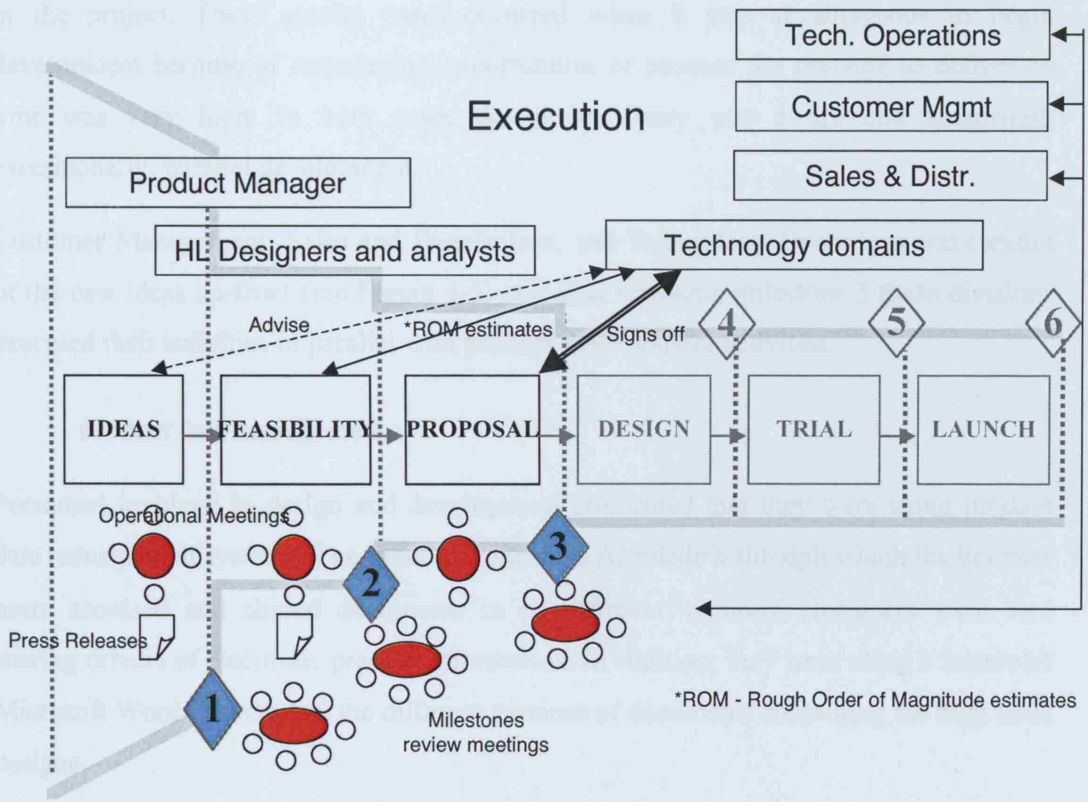

Figure 4-5. Activities and meetings that fostered the early involvement in design

Parallel development

The possibility of executing high level design in parallel with detailed design was to some extent restricted by the stage gate process. Documents and interviews revealed that activities from one stage to the other should continue only after milestones approval. This restriction was clearer in milestone 3 where full commitment of resources was authorised only after this milestone. An interesting trade-off appeared here: the pressure to introduce products before competitors versus the confidence that the new ideas contained the necessary technical and financial elements to succeed. One program manager describes this situation:

> Milestone 3 is a psychological barrier. Everyone is hoping that the review body gives the go ahead to their corresponding proposals, thereby authorising the estimated resources to detail design, develop and lunch a product.

Nevertheless, some managers admitted to developing some detailed design before milestone 3 was authorised. When this happened, they considered additional risk involved in the project. These special cases occurred when it was advantageous to begin development because of outsourcing opportunities or because the pressure to deliver on time was very high. In both cases the review body was aware and authorised, exceptionally, parallel development.

Customer Management, Sales and Distribution, and Technology Operations were aware of the new ideas up-front (see Figure 4-5) and after releasing milestone 3 these divisions executed their activities in parallel with product development activities.

Product data management

Personnel involved in design and development confirmed that they were using product data management systems. The most common was Accolade® through which the licensed users accessed and shared documents in its different versions. Designers were also sharing drivers of electronic product information. In addition, they were using a feature of Microsoft Word™ to control the different versions of documents containing the high level designs.

Teamwork and co-location

A positive attitude towards teamwork permeated the groups participating in the design and development of new products. Most people expressed their willingness to share responsibility for the development, to participate in multidisciplinary meetings, to consult or be consulted by peers before taking a decision, and to help other groups if necessary. This willingness to work as a team compensated for the disadvantages caused by the functional and sometimes geographical divisions in the company.

Although the company did not have co-location as a strategy, groups were collocated when the physical conditions were appropriate. For example, product and project managers, analysts and high level designers shared the same office. Despite the fact that the teams were not fully collocated (the specialist from Technology domain were not in the same office), the effect was positive.

Physical conditions happened to be one of the main constraints to collocate teams. The company was dwelling several buildings in a small town. These restricted conditions changed when the company moved on to a new building erected on the outskirts of the town. Nevertheless, the extraordinarily high number and diversity of the products being developed made it almost impossible to set fully collocated teams in each program. Instead, managers decided on the co-location of the groups based on the priority and type of the program. The teams that were not collocated performed very frequent meetings. To this end, the company was prepared with the necessary space; meeting rooms were observed everywhere.

4.1.5 About the relationship between NPD and PM

Two particular relationships observed in the company contributed to understand how NPD and PM are related. Firstly, the difficulties in implementing PRINCE 2 in the Product Development division where the NPD process was being applied, and secondly, the differences between the project management function and the product management function.

The NPD process and PRINCE 2

As has been previously described, PRINCE 2 was implemented after the NPD process. Regarding the relationship between them, documents explained that they should be complementary:

> The introduction of PRINCE 2 will not require significant changes to the NPD process. The NPD process is not a project management process or methodology. PRINCE 2 is a methodology by which we will manage all projects including NPD.

Managers in charge of the implementation of the NPD process explained the interface between the two:

> The NPD process is an end to end business process, is focused on commercial aspects. The way to develop this process can be done through a PM methodology. We are now using PRINCE 2, which is a way you run projects within the NPD process. The better you are in the project, the better your adherence to the process would be.

Clearly, the documents and interviews with the senior program managers in charge of the NPD showed that NPD was the process defining the *what* while PRINCE 2 was the PM methodology defining the way or *how* projects should be run. Notwithstanding, to some project and program managers the difference was not as clear the documents stated. To them, some sort of interference existed. Table 4.4 shows some comments in this respect.

Table 4.4. Comments about the relationship between NPD and PRINCE 2.

I know PRINCE 2 but I don't use it here because the organisation has used this NPD process and it knows how it works and this process gets things done, so there is no need to change the process.
Personally, I would think that we don't need to throw the NPD process away to be able to bring in PRINCE 2. I think that we could bring in parts of PRINCE 2 not the whole of PRINCE 2.
Yes absolutely, it is not clear as to the differential between the NPD process and the Prince 2 process. The NPD process is only a commercial dating process.... It goes through a milestone process which makes people think it is a project process and that's because people are using the word milestone as opposed to anything else; it's nothing to do with the PRINCE based process that sits behind it. So there has been a huge mix up in people's minds as to the fact that an NPD process is a Project Management process and it is not.
They have similar approval techniques, and the fact that it has stages is very similar and the fact that it has approval boards is very similar. Some of the roles and responsibilities are not the same; it doesn't have similar roles as the executive supplier.

Originally, the NPD process was designed at a high or aggregated level. After that, internal groups deployed it into more detail for the process to be operable. As a result, project management and design procedures were developed and incorporated into the

NPD process. Thus, when the company decided to implement PRINCE 2 (a project management methodology) both methodologies competed with each other. This helps to explain why people suggested that both methodologies had to be "blended", "merged", "synchronised" or "mapped". Furthermore, someone suggested the need for "princifying the NPD". In fact, the Eden project specification outlined the relationship between the NPD and PRINCE 2. The document included a conceptual schema aligning both processes originally conceptualised for commercial and delivery purposes respectively. Figure 4-6 shows a stylised schema of the original sketch. This aligning schema had to be refined during PRINCE 2 implementation to differentiate the elements pertaining to NPD from those pertaining to PRINCE 2.

However, the differentiation and alignment of the two processes was not trivial. Executives had to make crucial decisions regarding authority and responsibility for the development. For instance, the "NPD Review Body" was the highest authority for the development according to the NPD process. However, PRINCE 2 documents stated that the highest authority should be the project board, composed by program managers and heads of product development. Likewise, according to the NPD, the program leader should be the Group Chief Designer, and according to PRINCE 2 it should be the program manager.

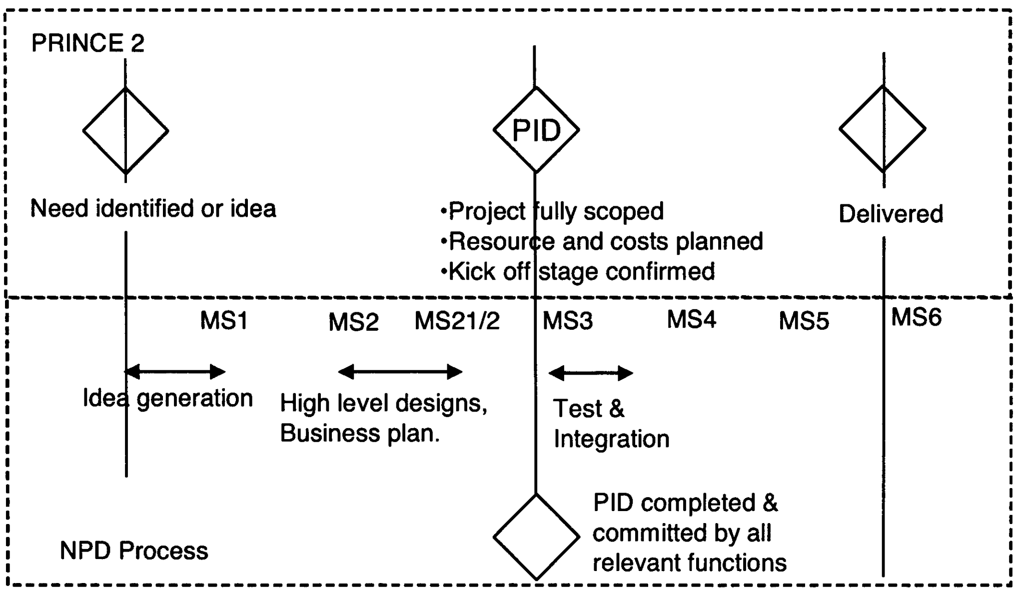

Figure 4-6. Aligning schema between NPD and PRINCE 2.

As mentioned before, design procedures were also detailed and incorporated into the NPD process, like the High Level Design and Test and Integration processes (see Figure 4-6). Thus, assuming that the company would have decided to unify all the technical procedures, the task of differentiating and aligning technical processes and the NPD process would also have been necessary (and perhaps problematic).

Structural changes could have caused or increased the difficulties to integrate the NPD and PRINCE 2. The creation of the NPD process was proposed and promoted by a commercially orientated division. At that time, the director of that division and his staff[2] believed that a process should be set in place to guarantee the commercial success of the products to be developed. Later, and for different reasons, the division was split into the three current organisational units in charge of the development: Product Management, Product Development, and Technology domains. Then, the NPD process was divided into two parts: the portfolio strategy, to be owned by the head of Product Management; and the "select" and "delivery" phases (the actual NPD process) to be owned by the head of Product Development. Thus, when a project management orientated initiative (Eden) was set to be implemented across the company, selling the idea to the Product Management and the Product Development directors could have been difficult, since both came from the commercially orientated division. This might explain why in Technology domain groups a smoother and faster implementation of Eden was taking place: because the Director had no direct responsibility for the NPD process, nor did he has a commercial orientation.

It is believed that two decisions were made attempting to achieve a better balance between commercial and project orientations. First, the Product Development director was assigned to the Eden implementation board. Second, one of the persons leading the Eden project who was responsible for the selection of PRINCE 2 had been moved to Product Development to lead the implementation of the NPD and PRINCE 2 in the group.

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[2] When the case study was being developed, that director was the actual Product Management director, and one of his staff members became the actual Product Development director.

[3] For comparative purposes, see also the list of tools and techniques normally used by product managers and project managers in the Appendix B of this case study

This person who had accumulated considerable experience in PM and NPD, was asked what process should be implemented first:

> It depends where you start from. We had a number of project management methodologies, we had a variable quality of project managers, we had no process, and therefore no decision, you need to put the process in. If we started a new company, and no process and no project management skills, then some of the basic skills of project management would probably have had to come first, then define the process. But really the two go hand-in-hand and one doesn't necessarily take precedence over the other.

These comments suggested that a PM methodology was not enough to define an end-to-end process to develop new products.

The relationship between the project management function and the product management function

The relationship between the Product Management function (represented by the product managers and their heads) and the Project Management function (represented by project managers and program managers) was interesting. In general, it was considered that the Product Management function was responsible for the commercial success of the product (revenue and profit), whereas the Project Management function was responsible for the time and cost of the development. Noticeably, the Product Management director had a higher hierarchical position than the Product Development director (Figure 4-2), and despite the fact that a board of directors had been integrated to take decisions, a manager commented “the Product Management director is the one who takes the final decision”.

One project manager and one product manager expressed the relationship in the following terms[3]:

> The way we work here, and the way it works in other organisations it is the responsibility of the product manager to define the requirements of the products. What is acceptable and what isn't. And then it is the responsibility of the project manager to deliver a product to meet those requirements. (Project manager)

> The product managers are expected to understand what the business wants as product. The project manager is to make sure that the business can deliver it. To manage the project to deliver the product. (Product manager)

The Product Management function was considered responsible for the performance of new products in the market and executives from this unit acted as sponsors of the projects. Perhaps because of this sponsorship role, the heads of product management groups (and not program managers) presented the program status in the milestone review meetings. This evidence suggests that the project management function was constrained to an "execution" perspective. However, program managers and executives stated that the company was fostering both program and project managers to develop a more decisive role in new product development.

Product managers had an active participation during the first two stages (Ideas and Feasibility) of the "select" phase. In fact, they coordinated the projects and passed the coordination role to program managers somewhere in the middle of stage 2, Feasibility (see Figure 4-4). After that, program and project managers led the projects until product launch. During the Design stage, product manager's role was something like "they need to be informed" and project managers from the product development and technology/domain groups coordinated the development.

At the end of the development, (during trials and product lunch) commercial areas (Sales and Distribution, Customer Management) had to be involved. Since project managers were not familiar with commercial issues, they involved product managers to act as a kind of informal coordinators of commercial teams, while project managers coordinated technical teams (Technology and Operations). Thus, a natural dual participation took place between the product managers and the project managers in order to complement commercial and technical expertise. This participation was facilitated through co-location, since both product and project managers were seated face to face.

4.1.6 Summary

In this case study NPD was considered as an end-to-end business process defining *what* products should be developed and PM (represented by PRINCE 2) as a process-methodology defining how the projects should be run. An aligning schema was depicted at the beginning of the Eden project, in order to illustrate how both processes fit to each other. Unfortunately, the alignment schema was not totally concluded and the two processes were competing each other mainly because the NPD process was detailed up to the point of also defining the *how*.. An experienced manager that had participated in the implementation of the NPD process and PRINCE 2 suggested that PM could be implemented first and then NPD.

PM was considered a "professional career" within the organisation. Project managers, program managers, and Sr. program managers received formal training and were certified according to their competencies. Even team members received a formal training about project management for them to understand their role in the project and their interaction with project managers. Program managers in this company led the development of programs or "propositions" and delegated into project managers the coordination of the projects that comprised such programs. Accordingly, program managers were engaged in the development at the beginning of the feasibility stage, to formulate plans and coordinating the participation of different groups.

The relationship between product and program and project managers was insightful. Product managers were responsible for the product in the market and program and project managers for delivering such products. However, during the development, both had active and complementary participation, due to their responsibilities and expertise. Interestingly, product managers, and not program managers, coordinated the initial two stages of the "select" phase.

Managers commented that the company had not launched a formal initiative to implement CE and most of the interviewees did not know the term. Those who acknowledge it had a rather different understanding. Nonetheless, it was discovered that in CE related practices were being applied. This discovery suggests that in this company CE was a slippery concept difficult to recognize by practitioners. The following quote made by a senior project manager stresses this lack of a proper understanding: "it depends on how you define CE".

Resources alignment and balancing in this dynamic environment was an issue that needed to be improved. During the first stage, "select", the assignment was done stage by stage and without much attention to achieve an optimal resource utilisation as it was believed that this condition was difficult at the fuzzy front end. During the second stage, "delivery", the assignment and control of resources was more carefully planned as most of the human-hours were invested in this phase. Nevertheless, the process to assign and balance the resources was still too iterative between the areas and carried out with tools like MS Project and spreadsheets.

4.1.7 People interviewed by roles

Role	Number
Project managers from Product Development group	2
Project managers from Technology domains	1
Program managers	1
Product managers	2
Designers	1
Chief designer	1
Process managers	1
Product release program manager assistant	1
NPD coordinators	2
Senior program manager in charge of Eden	1
Senior program manager in charge of NPD process	1
Total	14

4.1.8 List of tools and techniques

The following list contains the tools and techniques used in the company to develop new products. They were gathered from interviews or mentioned in the different manuals reviewed during the case study.

Business and commercial	Design and Engineering	Project Management
- Accolade™ - Business case - Market research - Competitors' analyses - Company performance analyses - Aggregate resource planning - Three years business plan	- Design FMEA - Accolade™ - Versions control feature of Microsoft Word™ - Shared drivers	- Accolade™ - Risk Management - MS Project™ - Planview™ - Gantt and milestone charts - Resource assignment - Product breakdown structures - Responsibility matrix - Communication

4.2 High Tech engines company

4.2.1 Company and products

The business unit, which employed around 2000 employees, belonged to a multinational corporate. The company produced high-tech power engines for the aeronautic sector and was a first tier supplier. The type of production can be classified as *make-to-order* and the production volume of every order or contract varied between ten and two hundred engines.

The company's core competence was engineering, covering research and development, design (product and process), and prototyping. Manufacturing and assembly facilities were dispersed in three countries and, in all, the organisation managed a network of about 650 product and service suppliers.

The company produced the engine's spare parts and offered repair and maintenance services during the engines's useful life, which extended to more than twenty years. The weight of the engines ranged between 100 and 500 Kg.

To cope with new challenging requirements the company made considerable investments in research and development. Although the engine's operation principles had remained practically unchanged since the first model was built for commercial purposes (around sixty years ago), the demand for new models or existing models with different requirements fostered the company to innovate its products constantly. For instance, a request for a model with 10% more power than a current model implied technological challenges in terms of materials (type and strengths), fluid mechanics, or control systems.

Typically the lead-time to introduce a new model was at least five years. More challenging requirements in space, weight or power entailed up to 10 years project lead-time.

The new orders' information system showed 140 projects being developed simultaneously. Some of these projects included new products or major modifications; others included orders for existing models with only minor modifications.

The company, founded over a century ago, had earned world-wide prestige thanks to its strategy for delivering superior quality products. During the interviews employees seemed to be proud of this prestige. For instance, when an interviewee was asked about the time he had been working with the company, he proudly answered "man and boy", signifying the long-term commitment of employees to the company. This background is important in setting the context in which new products were being developed, and also because this organisational culture was being changed.

Approximately ten years ago, executives realised that the company could no longer compete on a strategy based on highly engineered (high tech) products. Instead, a strategy based on reliable and commercially successful products had to be fostered. One program manager explained that, in order to implement the new strategy, the company was promoting a new organisational culture consisting of:

> Moving away from technically advanced, high-risk programs, to a company which is evolving their products at low risk, but is more credible to customers.

However, achieving the change had not been an easy task. People naturally resisted abandoning a long tradition of "perfection" in developing products, above all those managers and technicians who had been working in the company for a long time ("man and boy").

4.2.2 Business process strategy

As a part of new business goals, the company had restructured their operations by adopting a business process strategy. This strategy will be described in this section since it is necessary to understand the role of the new product development process.

The organisation, at a corporate level, set a plan to improve the quality system by "evolving from procedures to processes". The fundamental change was to move away from "what to do and how to do it" (procedures), to "what it is wanted to achieve, what the best way of achieving it is, and whether it has the capability" (processes). This, it was believed, would increase the reliability of the products and the credibility of the customers.

The challenge lay in generating the business processes that would regulate and improve any activity in all of the companies belonging to the multinational corporate body, including the business unit of the case study. To confront that feat, the company began by defining the top-level business processes and cascaded them throughout the different operational levels.

Nine top-level business processes were defined and inter-connected to assure consistency with all companies' operations. The resulting model, called Business Process Model (BPM), is depicted in Figure 4-7.

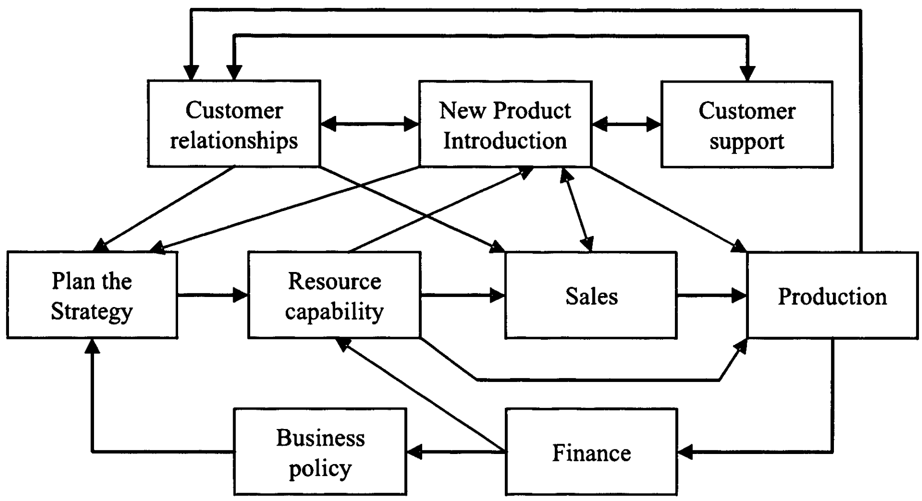

Figure 4-7. The business process model (BPM)

After defining the nine top-level processes the second step consisted of assigning a top-level executive as owner of these processes. Process owners had the responsibility of implementing, operating and improving their processes. It was particularly important to break down the business processes into operational sub-processes, and to make them match with the existing procedures.

The BPM was deployed and implemented as an exact replica in every business unit. For instance, at a corporate level there was an Engineering Director owning the top-level process "New Product Introduction". In the business unit of this case study, the person responsible for the right application of the process was a "Unit Engineering Director".

4.2.3 New product introduction

The New Product Introduction process

The steps to generate new or derivative products were described in the top-level business process "New Product Introduction" (NPI), which was defined as:

> A complete definition of the products or services, how to make, operate and maintain them and the commissioning of fully functioning delivery (i.e. production) systems capable of realising customers' solutions

One engineering expert metaphorically described the essence of NPI:

> New Product Introduction is posh way of saying develop a new product basically, but with the emphasis on doing it to meet a specific customer requirements.

The NPI process broke down in three key stages (Figure 4-8): preliminary concept definition, full concept definition, and product realisation. It can be appreciated that the NPI covers the three initial stages of a longer process. The remaining three stages ("Production", "Service Support", and "Disposal") were documented independently. This separation illustrates how an old procedure, containing the six stages, was adapted to match the new process strategy. The six-stage procedure was called the Engineering Procedure (EP) and it was aimed at design, production, maintenance and disposal of the products.

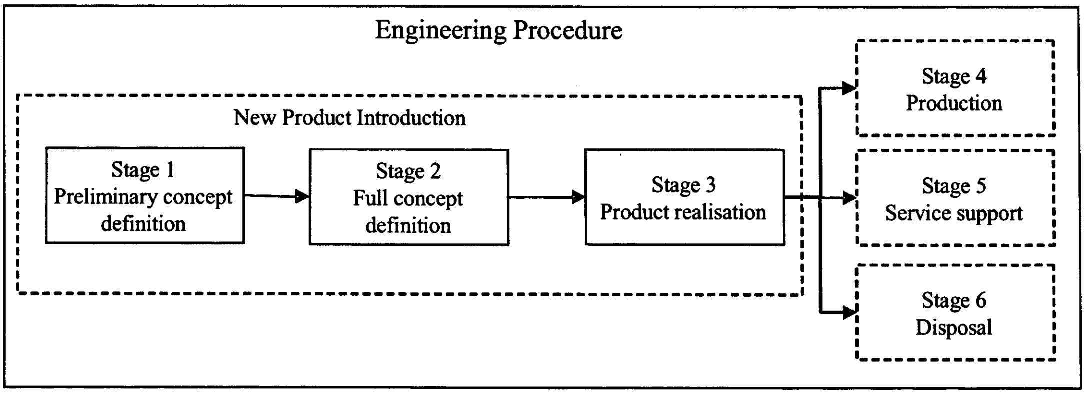

Figure 4-8. The New Product Introduction process

Each step of the NPI process was described in internal documents as follows:

Stage 1. Preliminary concept definition. The purpose of this stage is to develop and review alternative product concepts and their associated costs and risks, with the objective of presenting a single costed (sic) concept at Stage 1 exit which best meets the market opportunity and company business requirements.

Stage 2. Full concept definition. The purpose of this stage is to add detail to the preliminary concept defined in Stage 1 with the objective of delivering a risk assessed full concept definition and a detailed costed (sic) plan for stage 3.

Stage 3. Product realisation. The purpose of this stage is to provide sufficient information to consistently produce, build, operate, maintain and dispose a product which satisfies the customer specification, regulatory requirements and the company business need.

Organisation for the NPI

The organisational structure to develop new products is illustrated in Figure 4-9. The programs director was responsible for all customer contracts, including new and existing models. Program managers managed a specific number of contracts and depending on the magnitude of the program, delegated parts of the program to project managers, team leaders or work package managers (WPMs). These latter co-ordinated a number of team members or “doers” assigned by the Chief Engineer who performed the role of a resource manager.

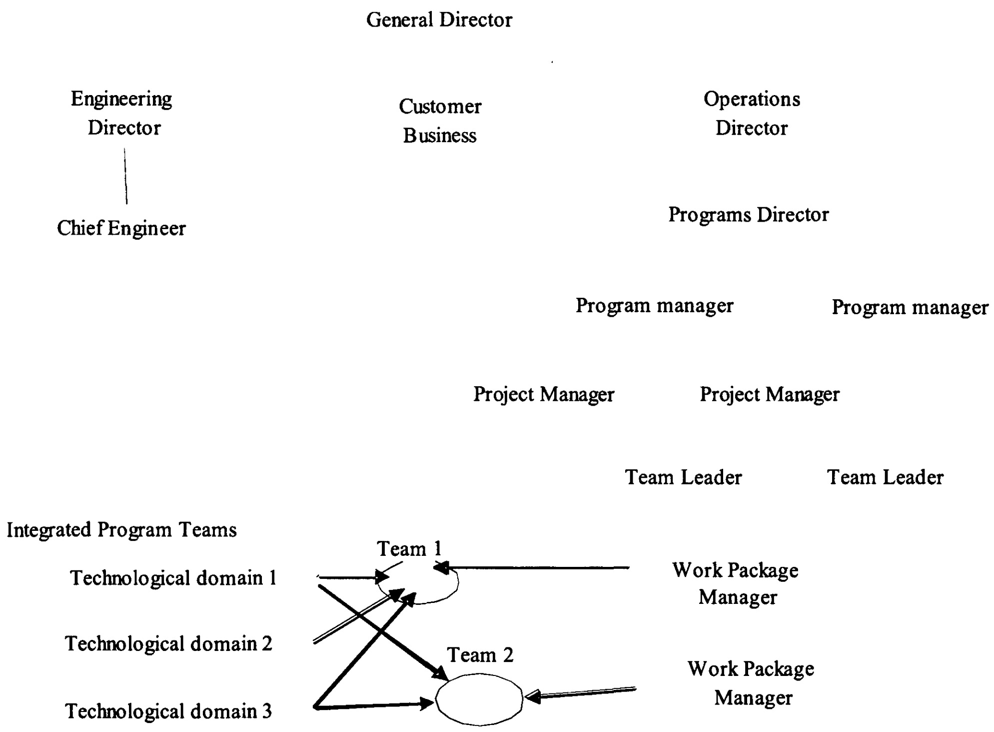

Figure 4-9. Organisation for the development

The organisation to develop new products was of a matrix-type where program managers had a strong engineering orientation. Because of this, certain programs were not assigned to program managers, but to chief engineers, and specialists were sometimes assigned as work package managers. During an interview, a program manager explained that he had a strong technical background because the phase of the project (achieving the product certification from regulatory bodies) required a program manager with those characteristics. This comment suggested that the complexity of the product justified the highly technical background of program managers or the assignment of chief engineers to programs.

However, there was another likely reason: the engineering tradition still hampered the new business process orientation. In this respect, a program manager claimed that the company was still trying to overcome the pure engineering orientation. In doing so, "people must understand that the company is here to make money and not to make the best engine ever". Moreover, one chief engineer admitted: "we sometimes overdo the engineering".

Engagement and disengagement of program managers

Managers from the customer business division (see Figure 4-9) visited existing customers and potential buyers to negotiate new contracts following the top level "Sales" business process. They prepared the business case based on the five years strategic plan, engaging program managers and technical experts for assistance. When a contract was awarded, the information of the business case (internal and external) was input in the orders' information system and then passed onto the program managers. Therefore, the participation of the program managers normally started at the beginning of stage 1 ("Preliminary product definition").

At the other end of the development, program managers handed over the program according to contract conditions. For instance, if the company was awarded a contract covering development, production and in-service support, a program manager was assigned to be in charge of the three stages because customers preferred to have one single point of contact with the company. In other kinds of contracts covering products characterised by high levels of innovation and long lead-times, it was common to change program managers at the end of certain stages because different skills were necessary from one stage to the next.

4.2.4 Integrated Program Management

The documented definition of Integrated Program Management (IPM) was:

> IPM is a program management methodology that is comprehensive, systematic and common everywhere in the Company. It is integrated with all the other principal Company processes through its link with the Business Process Model.

The corporate definition of a program was as follows:

> A program is a related series of activities, stretching out over time, intended to achieve defined objectives. It is characterised by the existence of a "Customer" who has the authority to agree the objectives and release the necessary funds.

The IPM was directly associated with the top-level business process "Plan the strategy". As a result, the corporate policy indicated the IPM approach should be applied "from directors down" as a common framework in every program undertaken by the company. In this case, the IPM role was similar to PRINCE 2 role in Company 1.

The IPM framework was based on seven principles. These were described in internal documents as follows:

1 .- **All activity is defined by programs**. All business is defined in terms of programs, be they private venture, customer funded, resource capability, marketing campaigns or improvement activities.

2 .- **Programs determine resource group size.** Resource groups do not exist as self-sustaining entities but are sized to support customer demand and which are authorised by program budget.

3 .- **Commitment-acceptance.** Plans cannot be committed until tasks, resources and budgets are sufficiently reconciled, and a risk quantification and mitigation plan has been agreed.

4 .- **Managing the resource.** It is a resource group manager's job to find the resources (internal of external) to commit to a plan, recognising the lead-time needed to change resource levels and the need to deliver continuous improvement.

5 .- **Financial control.** No other financial authorisation of approved delegated program budgets will be required, provided that the cost is regularly accounted for in terms of earned value and program performance.

6 .- **Conflict resolution.** Resource managers must satisfy all of their commitments to customers. However, the project/business hierarchy must ultimately reconcile budget and resource priority.

7 .- **Change control.** Requirements can only be changed by agreement with the program manager. Before a change is made the owner must agree, and then re-commit.

The IPM was also described as a "process of managing a program" from customer requirement through to the delivery of the product. The process was simplified by breaking it down into four phases: pre-program evaluation, planning, execution, and close-out. The process was apparently broader than the Pm execution perspective as it included a pre-program evaluation stage.

The IPM framework was relatively new; "we are still learning from it", affirmed an engineering director. Before the introduction of IPM, the work was more "functionally-oriented" and the concept of *resource manager* did not exist (see principle 4 of the IPM). Before IPM, the program manager was also accountable for staffing the resources, so there was "inconsistency across the programs".

The SAP-PS™ software provided the technical means for integration. SAP™ was introduced in the company before the implementation of IPM and was used as an MRP[4] tool. After the implementation of IPM (or as a result of it), the SAP-PS™ module was incorporated to integrate operations and programs under the same ERP[5]. Additionally, SAP-PS™ made it possible to standardise the application of the Earned Value method to measure the performance of every program in the company.

Functional units accustomed to working with programs (like R&D or Engineering) adopted the IPM framework faster than functional units accustomed to working with ongoing operations (like Finance or Quality). Regardless of the pace, the company supported the program through the Intranet, workshops, assessment tools, and internal consultants.

Program management training program

To support the application of IPM, the company had developed a program management training and certification scheme. It consisted of PM courses and computer based training workshops where people learned and practised with MS Project™, Project inceptor™, and SAP-PS™ (see a list at the end of the case study). Additionally, the company had structured a program for people interested in pursuing an MSc in project management (a joint venture with a local university).

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[4] Materials Resource Planning

[5] Enterprise Resource Planning

People working in programs were supported in order to achieve a PM certification of proficiency issued by external organisms. These could be the Project Management Institute in USA, or the Association for Project Management in UK.

Resource management

According to the concept of Integrated Program Management, the resource management function was "to build capability into the programs". The resource manager, a role assigned to the chief engineer, staffed the teams with the corresponding specialists (see figure Figure 4-9). Thus, very often, the resource manager and the program manager were involved in a process of "convoluting negotiations" for resources.

Once the resources were negotiated and assigned, the resource managers' main responsibility was to support the development with their technological expertise or replacements. In other words, resource managers no longer performed as functional heads, but as expert advisors and coaches. The assigned specialists and the work package managers were bestowed with autonomy and responsibility to make their own decisions adhering to the IPM seven principles and following a basic rule in matrix organisations: the specialists were responsible for the *how* and the work package managers for the *what* and *when.*

The SAP-PS™ tool provided both cost and accounting support for working under the principles described above. The software contained the information about available resources for new programs. Once the resources were assigned, the information was input into the software and each specialist was responsible for accounting the time they assigned to each program in which they were participating. The work package manager was in turn responsible for the costs of the work package. When a team finished its work package, the resources were "released", in the SAP PS™ and the costs were reconciled with the program budget.

The organisation still had some problems in working with the SAP-PS™ system. Some team members and managers were not accustomed to booking their time in the system and therefore the information was inaccurate. Furthermore, SAP-PS™ used the Earned Value method to measure performance. This method allowed program managers and executives to monitor program progress by recording and analysing, at the program level, aggregated cost and time indicators. However, some program managers and executives were resistant to use the Earned Value indicators because they were more familiar with "classical" tools like Gantt or milestone charts. Additionally, the software did not provide detailed information at the work package level; "SAP is not designed for day to day project management". Hence, work package managers, team leaders and project managers applied other PM techniques like the Gantt chart or the Critical Path Method, supported by smaller PM software packages. All these problems with the SAP-PS™ and the Earned Value method complicated the implementation of the IPM approach.

The "Directing Programs" process

To manage the NPI process the company had designed and applied the "Directing Programs" (DP) process. Internal documents stated that:

> The Directing Programs rules direct appropriate project management control of both the business and technical aspects of the NPI process.

The DP embodied the principles of IPM and therefore the basic elements of the "Plan the Strategy" top-level business process. In addition, it set the business and technical reviews that had to be controlled during product introduction (Figure 4-10).

Some questions emerged at this point in time during the fieldwork. First, why was the NPI managed under the DP (Directing the Programs) process and not managed directly under the IPM (Integrated Program Management) framework? Moreover, the DP was a subset of the NPI and therefore owned by the Engineering Director, whereas the Financial Director owned the IPM. Hence, was this different ownership not disrupting the strategy of unique process ownership? Opinions differed; engineering-orientated people believed that the DP followed the IPM principles and therefore there was no inconsistency. Others (program management orientated) argued that the NPI should be managed through IPM. In any case, the company seemed to be working on the safe side, "better in there twice than not at all" justified a program manager.

4.2.5 Concurrent Engineering

CE understandings

In the 1980s the company launched an organisational initiative to improve the engineering processes. As a result of this effort, a set of practices to systematically promote early involvement of manufacturing engineers in the design phase was consolidated. These practices were identified as Design for Manufacturing (DFM). Further improvements brought about Design for Assembly (DFA) practices where assembly engineers participated in the design phase. The implementation of these practices was later associated with academic terms like Simultaneous Engineering and Concurrent Engineering. As a matter of fact, the company was a pioneer in CE practices and case studies about these developments were written in academic journals[6].

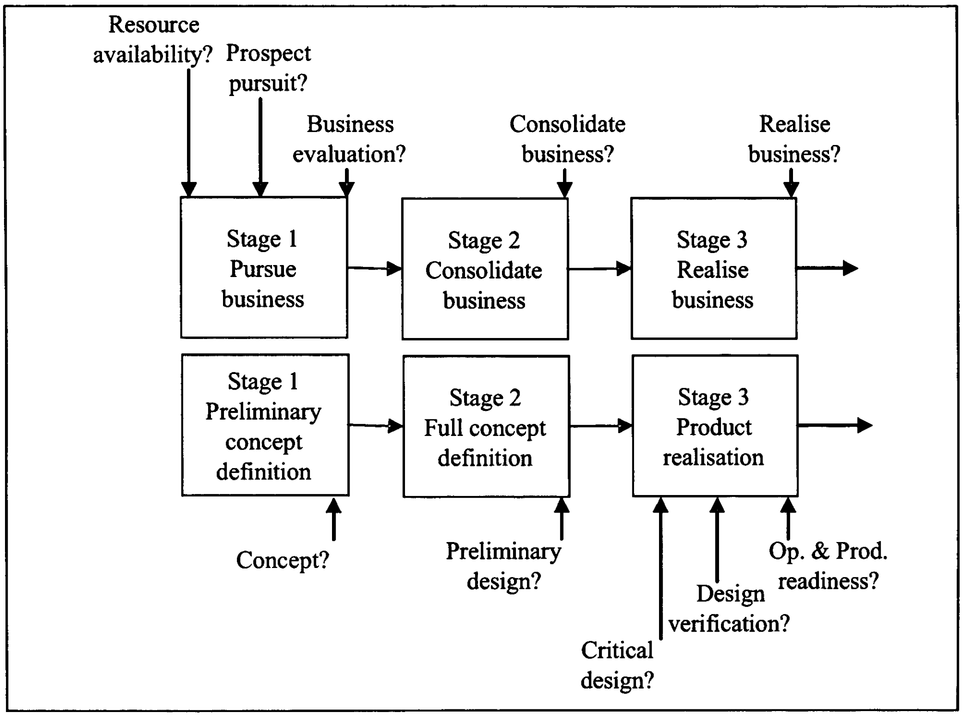

Figure 4-10. Business and technical reviews as stated by the "Directing Programs" process.

Managers and specialists were asked about their understanding of CE. Table 4.5 shows the main answers. In general, people understood CE as the early involvement in design and parallel working. It should be noted that in the third comment and fourth comment

[6] References cannot be given to preserve the anonymity of the company

CE is defined using the term concurrent, a lack of coherence that had been highlighted in the theoretical framework section (see Ch. 2).

Interviewees emphasised that the main benefit of CE was to avoid the re-work typically caused by designing something which was difficult to manufacture. Time compression was also mentioned as a benefit since starting downstream activities before ending upstream activities reduced the lead-time to design and manufacture.

When asked about CE tools and techniques, some interviewees explained that to enable CE it was necessary to promote communication between the teams. Some other managers mentioned co-location. One engineering director remarked that managing the workflow made CE possible.

Table 4.5. Different understandings of CE.

Concurrent engineering is about designing the bits; at the same time you are figuring out how to make it effectively; at the same time you are validating the bit, such that when the finished part arrives in the store you produce the inspection drawing.
It's about evolving a product on a very much iterative basis, trying to get away from the thought process that certain activities cannot start until other activities are finished, but really you can work with other aspects of the design chain much earlier and shorten the overall lead-time as a result. So for instance, you might ask the supplier to come into the company to discuss the actual design you want to undertake a lot earlier in the process than you would normally.
It's trying to develop a product and produce it for production, you know, in a concurrent manner, in the same sort of timeframe.
It is the gradual release of definition as you work through a series of release gates, so you're releasing definition into manufacturing before you've actually completed it, you're evolving the design of a new product concurrent with manufacturing rather than end to end, where you produce a design and you detail it and then kick it over the wall to manufacturing, where they then find they can't make it.

Reaching concurrency was a feat that demanded intensive information exchange. All people involved had to be aware of the precise moment at which to release information to the downstream functions. The following comment reveals this stringent condition and shows that concurrency was pursued with suppliers as well:

> There is no reason why you should hold back designs if the supplier knows, for instance, that there will be further issues with the drawing later on. But in consultation

> between the two parties, the supplier will understand which areas of the component are still in question. He will also understand what level of confidence he has in going about his tooling estimates, and planning, but any contribution the two parties can make to that process is a valuable one.

One program manager stated "the old sequential mode was easier to manage...the level of effort in CE is higher in my view". For this reason, engineering groups were developing sequencing models based on information inputs and outputs. Matrices of information resulting from these models revealed opportunities to reduce the lead-time to design and develop products. Thus, although Gantt charts were being used, what was driving the sequence was the data flow, not just the simple logic task linkage. This evidence confirmed that DSM-like tools were being used by engineering people, rather than by program managers.

The researcher then asked the interviewees why they had not mentioned techniques typically addressed in the literature, like, FMEA, CAD/CAM/CAE and PDM systems and the like. Managers and specialists commented that most of these tools were applied in the company, however, they did not associate them with CE. For instance, Failure Mode and Effect Analysis (FMEA) was classified rather as a product quality tool; CAD/CAM/CAE systems were associated with product engineering; and Product Data Management (PDM) as a tool for managing product changes. However, they recognised that those techniques could effectively be enablers of CE (see the complete list of techniques associated with engineering and manufacturing at the end of this case study description). Thus the many practices grouped around CE by academics were not identified as such in this company.

Most persons interviewed associated CE with the concept of integrated program teams (IPTs). For instance, they affirmed that the company was formally applying CE "because we have IPTs". Indeed, IPTs were an essential component of the "Integrated Program Management" way of working. Thus, the next section addresses the operating principles of the integrated program teams.

Integrated program teams (IPTs)

The following description made by a program manager is the best way to introduce the purpose of the IPTs:

> For instance we are going to put a proposal into a customer company to supply engines. The problem we have is that we do not have a product today that will satisfy its requirements, so the question is well, do we supply something we do have but it is non-compliant with the requirements? Or do we evaluate how we can improve the product, how much that would cost, and on what time scale to satisfy their requirements? To be able to come to a suitable conclusion, a lot of business and technical discussion needs to be held, and we only have two weeks to do it. So the most appropriate way to go ahead would be to formulate a dedicated team aimed specifically at coming to resolving a solution to that problem. And through that dedicated team and regular meetings, we know who the focal point is, and there's regular communication between all the other members, and everybody can contribute on that basis to come to a solution. I think that'll be a lot more effective than the program manager running around saying well here's the results from the performance, can you evaluate these please and then he sits alone and evaluates, that's not very effective.

Thus the IPTs consisted of groups of people brought together to solve a specific problem. The members of these teams were skilled in different disciplines as required by the type of problem to be solved. For example, in the situation described above, business and technically skilled people worked together. Through intense communication and individual contributions, the teams reached better and quicker solutions than working on an individual basis.

A corporate policy stated that the IPTs were the working principle to execute any program. Hence, any activity, whether financially, quality or production oriented, had to be performed on an IPT basis so long as it was required to solve a problem or to produce a change.

IPTs were set up as early as possible to fulfil customer requirements since the company recognised that "the life cycle costs are locked in long before incurred costs start to appear". Large programs required a hierarchy of IPTs. Standing at the top, a group called "core team" dealt with the whole product. From the top level down, IPTs were integrated to carry out sub-systems and components. IPTs of the second and third level were disbanded when they finished their tasks. The core team could only be disbanded when all of the program objectives were achieved.

To ensure constancy of purpose and to promote concurrency between the different levels of IPTs, leaders of second and third levels participated in meetings with members of the core team. Therefore, program managers, project managers, or the team leaders participated in meetings at different levels with different teams. Thus, they managed technical interfaces and were able to co-ordinate the schedule of each team which enabled them to put together and monitor the overall schedule.

Once the budget for the work package was defined, the IPTs had financial autonomy to act upon it. To ensure financial integration across the whole program and the business, the IPTs were staffed by a person especially skilled and equipped with tools and techniques to "manage the money". The finance resource manager was primarily responsible for assigning these specialists and for technical support.

Another important characteristic of the IPTs was co-location. This strategy is best described through the following business policy:

> Co-location is definitely preferable, especially for the "core" team members, but it is not essential for all IPT members. It has been found repeatedly that the initial disruption of relocating people to single site pays off handsomely in terms of concurrent engineering, communication, unity of purpose, team spirit and so on.

Underpinning the company's policy of collocated IPTs, a vast training program had been created comprising technical issues and human related skills to enable the work in teams. In this respect, the company stated that:

> Where teams have shown most success, it has come about because of their continuous development during the course of the program. Projects on any significant size must set up their own arrangements to train, facilitate and coach the team towards better and better performance.

Interestingly, specialists in the company with the highest degree of expertise were not allocated in IPTs; their main task was to cross-fertilise the knowledge acquired between the different IPTs. The basic concept is explained in the words of one of these specialists:

> In my opinion you still need a core of people who are not associated with an individual project or an individual IPT. Because without core groups how can you cross-fertilise the information from the projects and IPTs if everybody does their own thing? This project or this IPT is doing a specific job and this team over here is doing another specific job. Then you need somebody in a core group to make sure that knowledge is shed or shared.

Through this group of experts, the company ensured that specialists in the IPTs were acquainted with the latest technological advances in the company. These cross-fertilisers were in essence the "technology brokers" identified by Hargadon and Sutton (1997) which make past solutions relevant for current problems. These specialists happen to alleviate a particular problem of the product-oriented organizational structures; these structures tend to "affect the ability of specialized technical talent to keep pace with the most recent technological developments" (Gerwin and Susman, 1996: 122).

However the role was not free of trade-offs. The time of each of these persons was not easy to manage under the accounting principles of 'Integrated Program Management', where everyone had to be in a program. Frequently, these specialists were called upon to give advice to an IPT during a meeting. Hence, their participation in terms of time was limited to one or two hours, distributed among many teams, and difficult to plan.

The company was undergoing other burdens in articulating the IPT policy. A particular problem was the lack of sufficient engineering capability. The ideal case was that every IPT contained a specialist working full-time or at least part-time. However, sometimes there were not enough specialists and the IPTs had to work without them during certain periods.

Another difficulty was the geographical distribution of the company's facilities and the dispersion of the supplier network, making it cumbersome to collocate teams. To overcome these constraints, the company was moving increasingly to virtual work.

4.2.6 Relationship between NPI, IPM-DP, and CE

One program manager conceptualised the relationship as a mixture of processes that are enacted in developing new products. To him, these processes interact with each other but not all of them occur at the same time:

> So it's the evolution of how you go about turning the customer requirements into a product, and through that process, and it is a process, you will incorporate other processes, more detailed, more well-defined processes, such as programme management, such as concurrent engineering, and there may be others.

An engineering director who had participated in implementing in IPM, NPI, and IPTs, was asked about the chronological order in which the company had implemented these approaches. He answered:

> There has always been program management, because you can't do anything without program management, but the program management we have today, and the way we do program management is completely different to the way we did it 20 years

> ago. What we haven't had before is integrated program management and the IT system to support it and the IPM philosophy, which is only five years old. Prior to that was concurrent engineering, which I said we started looking at about mid-80s. First in place was processes; what do we need to do? How do we do it? Then we've taken the same basic processes, altered how things happen, when they happen to provide concurrent engineering, and then we've taken that evolving situation and wrapped around it a way of more effective program management and resource management.

This comment shed light on the likely order of implementation and it does not happen to differ greatly from the data obtained in company 1. The comparative data will be presented in Ch. 5 and the analysis in Ch. 6.

The difference between IPM and program management was put in the following terms:

> Program management was much more segregated; each individual person had his own individual plan, and then went and tried to manage that plan, but the plans were only as good as the resources we get, we had no low-capacity resource balance, anything like that.

Apparently, program management as applied in this company and compared to IPM was similar to the PM execution perspective.

Nonetheless, all of the interviewees confirmed the high degree of relatedness and the difficulty of stating a clear separation between these approaches. One head of program management put it in the following words:

> The thing about concurrent engineering is that it's saying that you're going to make sure that the right people are there at the right time to make the right decisions ... the fact is that IPT says the same thing, program management says the same things. There isn't actually any difference between them.

Although program and project managers were familiar with the concept of CE, some of them admitted to not being fully involved with it. They commented that the "design community was more involved with CE". Indeed, the specialists interviewed gave the most useful hints about CE practices and tools. This evidence suggested that CE was applied by specialists, rather than by program and project managers. Moreover, training programs on PM did not include any specific course about CE.

Despite the fact that some project managers and specialists mentioned that CE helps to reduce rework, there was a corporate program management policy that could be interpreted as a recommendation to avoid simultaneous or overlapped work:

> Good program management says that a phase may only be entered when its predecessor is complete. In real life the phases overlap somewhat. However, the wise program manager will make haste slowly and ensure each phase is complete before committing significant resources to the next. It is universal experience that failure to complete each stage sharply increases rework, delay and costs.

This policy is comparable to the opinion of PM authors stating that CE is a risky approach because it is prone to rework. This apparent contradiction will be analysed in Chapter 6.

4.2.7 Summary

In this company, an NPI (new product introduction) process was considered a top level business process. IPM was conceptualised as a program management framework to manage any program in the company. According to a program manager, IPM was beyond program management as the latter was more segregated. Additionally, IPM processes included a pre-program evaluation stage. These two observations may indicate that the MP (the Management of Projects) broader perspective was present in this company. Moreover, some PgMgrs were certified under the APM certification scheme which is, as reviewed in Ch. 2, a PM framework covering this perspective.

The understanding of CE was fairly homogeneous between practitioners and basically composed of three elements, simultaneous development, early involvement in design, and teamwork (through the IPTs). Although the company was a pioneer on applying CE-related techniques like DFM and DFA, the organisation had not launched any initiative to implement it. Instead, the application of these practices was associated to the academic term of CE. Although many practices associated to CE in the literature were being applied in this company, practitioners did not relate them with CE. This seems to be a confirmation that academics have grouped too many methods around CE.

Engineering groups were applying DSM-type techniques to schedule their design activities. This way of scheduling was driven the development, instead of the Gantt charts. In fact, project and program managers seemed to be less familiar with this and other CE practices, as one program manager commented "the design community was more involved with CE". Likewise, PM training programs did not include CE courses or workshops. Perhaps because this lack of a thorough understanding on CE, a program management policy recommended avoiding concurrency since it might engender rework.

Particularly interesting was the fact that program managers were engaged in the process to develop new products at the beginning of stage one and were disengaged at different stages according to contract specifications.

A program manager explained how CE, NPD, and PM evolved in the organisation. PgrM was first in place, then CE practices and latter the NPI processes together with IPM. However, PgrM had been evolved to IPM which was more integrated. Although the relationship between the three approaches was difficult to precise by the interviewees, some of them explained that NPI and IPM were interrelated processes that broke down into work packages that were developed concurrently by the IPTs.

4.2.8 People interviewed by roles

Role	Number
Specialist Engineer	1
Program Manager	2
Head of Program Management	1
Assistant chief engineer and project manager	1
Chief Engineering and Program Manager[7]	1
Total	6

4.2.9 Tools and techniques

The following table contains the list of tools and techniques mentioned by people or documented in the different manuals reviewed during the case study.

Business and Commercial	Engineering and Manufacturing	Project Management
- Business case - SAP-PS™ - Five year business plan	- Design and process FMEA - Design for Assembly / Manufacturing - CAD/CAM/CAE - PDM - Information Dependency matrices - SAP-PM™ - Data flow management - Communication	- Project planning - Resource planning - Risk Management - WBS - Gantt Charts - Critical Path Method - Earned Value Methods - MS Project™ - Project Inceptor™ - SAP-PS™

[7] Three interviews (six hours) were carried out with this person because of his knowledge about product development.

4.3 Control systems company

4.3.1 Company and products

This company supplied control systems and services to the aerospace and defence industry as first and second tier supplier. The number of workers in the company was, roughly, two thousand.

Managers defined the nature of the company as a "systems integrator" because, rather than a single product, the organisation designed, developed, manufactured and assembled electronic controls (software and hardware), actuation controls, and engine health monitoring systems for aircraft manufacturers. The activities were distributed throughout different regional and overseas facilities. This geographical dispersion complicated the integration of activities to develop new products.

The production type could be defined as "make-to-order" since the company did not produce units or parts to be sold via retailers. The company rarely produced more than two hundred "high value – low volume" kits per order. System components varied from electrical or hydraulic mechanisms to electronic control systems composed by mechanisms, instruments, hardware, and software. Although the physical principles of this technology were known, the level of innovation was driven by challenges imposed by new dimensional, mass or safety requirements. It is estimated that more than 30 new products were being developed at the same time.

4.3.2 New Product Management (NPM)

The NPM process

The NPM process consisted of five general phases as shown in Figure 4-11. Seven strategic reviews, known as "gateways reviews", were carried out along the process to ensure consistency with business goals including *go no-go* decisions, program priorities, investments and resource assignment.

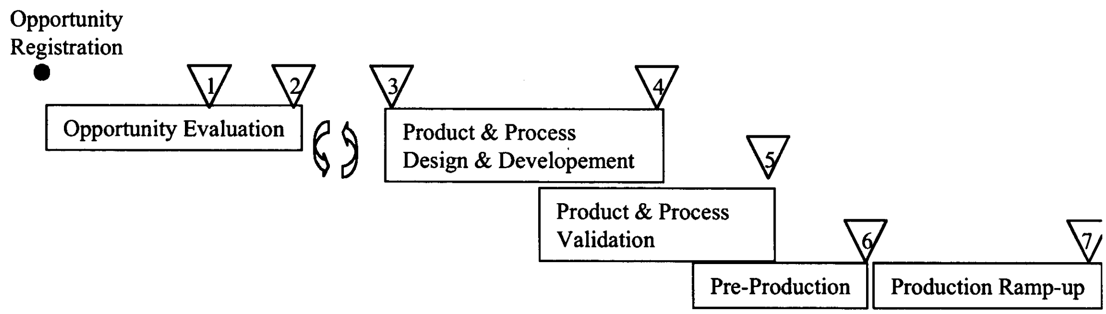

Figure 4-11. "New Product Management" process and gateways reviews.

The NPM process displayed above shows an overlap between three phases. This indication of simultaneous development was not observed in the product development processes from other cases. Indeed, when a program manager was asked how the company articulated concurrent engineering, he affirmed; "it is embedded in our NPM process".

Each stage of the NPM process was briefly described in internal documents as follows:

Phase 1. Opportunity evaluation. The project is registered and allocated a unique number and this is recorded on the local project register. An initial classification of the project will be proposed by the project owner at registration. A Project Manager and core team are identified. An initial assessment of the viability of the opportunity is made, including an outline project specification and a plan for the opportunity evaluation phase. The project manager will determine if the project is a Systems Project and subject to systems integration reviews. Gateway review 1 approves the detailed development of the proposal and the commitment of resources to deliver it. Following approval at gateway review 1 the proposal is developed by the project team. The proposal is approved at gateway review 2 as being economically viable project with acceptable business risk and fit to the business strategy. The availability of resources to complete the project, with respect to resources committed to existing projects and all other potential proposals must be confirmed at this time. Thus only approved proposals with confirmed resources are submitted to the customer.

Following approval of gateway review 2, the proposal is submitted and then negotiated with the customer. Upon contract award to the company the project plan is updated and targets established for all measurements of performance in preparation for gateway review 3. If the contract is not awarded, a review will take place and the lessons learned will be recorded and fed back to the Project Manager/s and project team by the Program Manager for use on future projects.

Phase 2. Product and process design and development. The concept is refined and detailed to produce a product design and manufacturing plan for production. This work is undertaken by a collocated multi-disciplinary team representing all required departments. The involvement of suppliers and customers is also key to the success of this phase. Product design (which includes system design, hardware design and software design where appropriate) will start with a confirmation of design concept. Product and process designs must be developed concurrently to ensure compliance with customer and company requirements and may involve development units and testing to prove the design proposal. Risks associated with the project are assessed in detail, recorded and managed.

Phase 3. Product and process validation. The product and manufacturing processes are fully documented and validated to ensure that they will meet the customer and company requirements. The phase ends when the performance of the equipment will have been demonstrated. Ability to manufacture piece parts is demonstrated; the build procedure and acceptance test procedure are approved. The qualification testing plan has been approved by the customer. If the product is a system then validation will include system integration and system testing.

Phase 4. Pre-production. During this phase confirmation is obtained that the manufacturing process and facilities (including those at suppliers) are capable of producing the product in the required volumes. Qualification testing, in accordance with the test plan, starts once validation is complete and is authorised at gateway review 5.

Phase 5. Production ramp-up. Production ramps up to meet the customer's schedule. The team is still available to address any problems experienced during this phase regarding the product or the process. Any outstanding endurance or reliability growth testing will be completed and certification will be sought from the appropriate authorities. The phase ends with the transfer of responsibility for the product and process from the project manager to Manufacturing, Supply Chain and Operations. Before the project team is disbanded, the lessons learnt from the project will be documented and input into the continuous improvement process. The objectives in the project plan are compared with the project achievement.

In general, the NPM process was similar to the NPD process of case 1 and to the NPI process of case 2 in that they were considered strategic business processes to develop new products.

Organisation for the development

The organisational structure of the company is outlined in Figure 4-12 where the division in charge of new product development, "Product and Technology" division, is deployed in more detail.

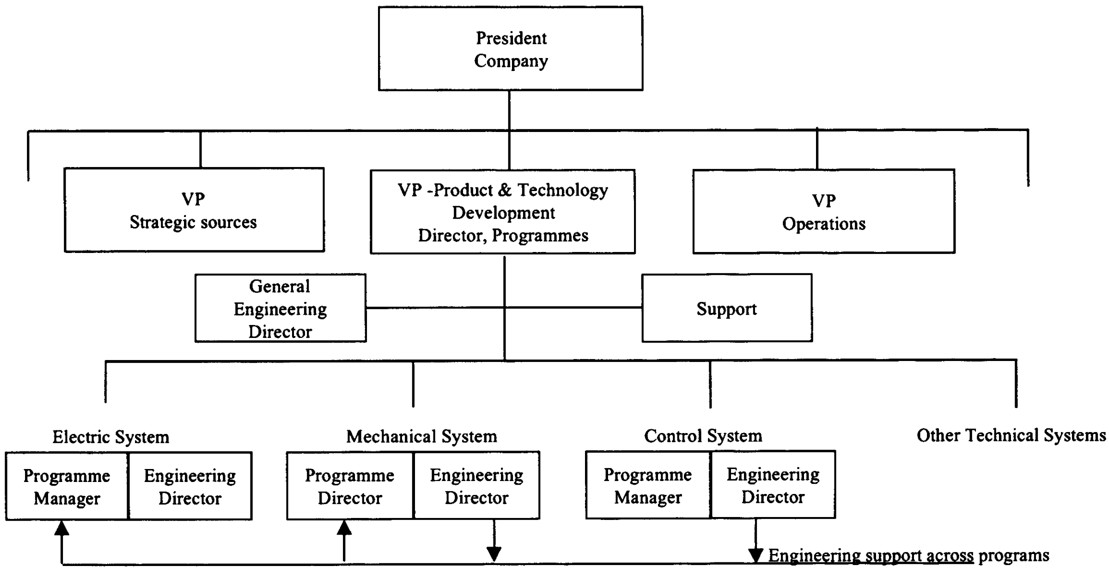

Figure 4-12. Organisation for the development.

Before the company was organised as shown above, a Program Management division led programs to develop new products and an Engineering Division assigned the necessary product and process specialists. Executives then believed that the engineering group was, to some extent, evading its responsibility for the programs being developed. Therefore, they decided to merge both divisions into the Product and Technology Development division and both program managers and engineering directors would be held responsible for the development of the programs. The shared responsibility was delegated "in cascade" as shown in Figure 4-13.

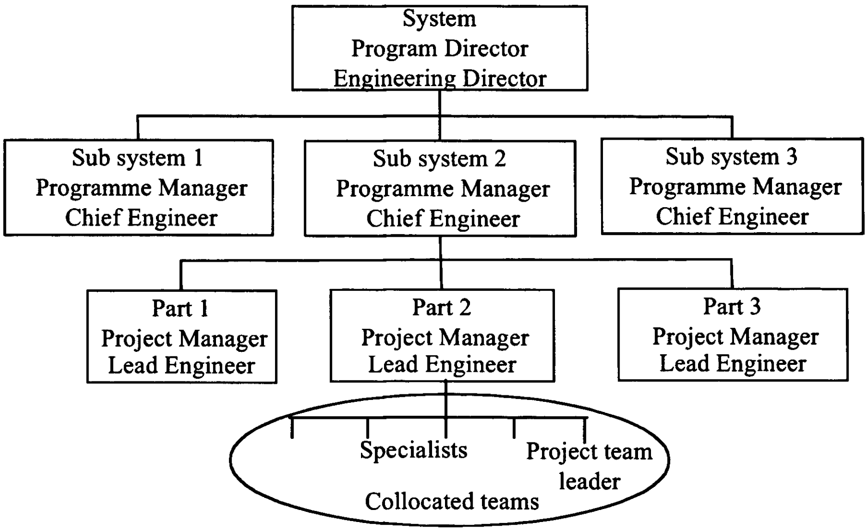

Figure 4-13. Dual responsibility and hierarchical structure for product development.

Every engineering director led a group of specialists including chief engineers, lead engineers and the specialists. Correspondingly, every program director delegated responsibility to program managers, project managers and project team leaders successively. The team leader was a specialist included in the collocated teams who had co-responsibility for the achievement of the project deliverables and baseline costs as agreed with the project manager and lead engineer.

The company was still learning about the advantages and disadvantages of the new type of organisation. The fact that responsibility was shared was discussed mainly between program managers and functional heads. One functional manager affirmed that the organisational changes occurring in the company reflected a pendulum effect. First, the responsibility of the development lay with the functional groups, later it rested on program managers; actually it was somehow in the middle, laying the responsibility with program managers and functional heads. This kind of dual responsibility has been reported by Hobday, where the rationale is to try to overcome the need for project managers "with a super-human range of talents" (Hobday, 2000: 887).

Engagement and disengagement of program managers

Customer business managers pursued business opportunities and lobbied prospects or clients, and consulted program managers to clarify technical or managerial aspects (for a list of techniques related to this business related step of the process, refer to the end of this case study description). Formal engagement normally occurred somewhere in the middle of the Opportunity Evaluation stage; that is, after gateway review 1. This earlier involvement facilitated the transition of the contract to program managers when it was awarded. Program managers were held responsible for the development of the program after gateway review 3, that is, at the start of the Product and Process Design and Development stage. Customer business managers remained in contact to support program managers with any issue relating to the business case. Program managers normally handed over the project to production staff at the end of the last stage: "Production Ramp-up". At that point in time, the team disbanded and lessons learned were documented.

Interestingly, program teams could extend their activities to provide product-related customer services such as maintenance or revamps. A project manager commented that these extended services imposed a sort of "cradle-to-grave" responsibility for program and project managers and their teams. These "in-service teams" worked under the principles of program management and concurrent engineering that will be explained bellow.

Support and resource management

The NPM process had been implemented four years ago. The process was owned by the program directors who were "responsible for co-ordinating any changes employees may wish to make to NPM manuals". Site program managers (SPMs) assisted program directors in the implementation and improvement of the process.

The process to allocate resources started when program managers planned their programs and broke them down into specific work packages. Then they defined the necessary skills set to develop each work package. The information was entered into an electronic database, and engineering managers then allocated people matching those requirements. Disputes about resource allocation were resolved through a forum called the "engineering resource council", where program managers and engineering managers joined together. The SPMs made recommendations on the best allocation of resources based on the company's resource capability. SPMs also managed the resource database which was an internally developed spreadsheet-type tool to collate the resource information. However, part of the consolidation of resources between sites had to be done manually since the skills set definition was not standard on all sites.

4.3.3 New Product Introduction Process (NPI)

Attention is now turned to another key process to develop new products applied in the company, the NPI process. Internal documents stated that:

> The NPI specifies the requirements associated with introducing a product into service or modifying an existing product. It covers the key aspects of product introduction including the engineering, production readiness and in-service readiness process.

Figure 4-14 outlines the NPI process showing the different phases and milestones to develop a system and a product. The documentation supporting the NPI is represented in the middle. The different phases and milestones of the production and in-service readiness processes are shown at the bottom.

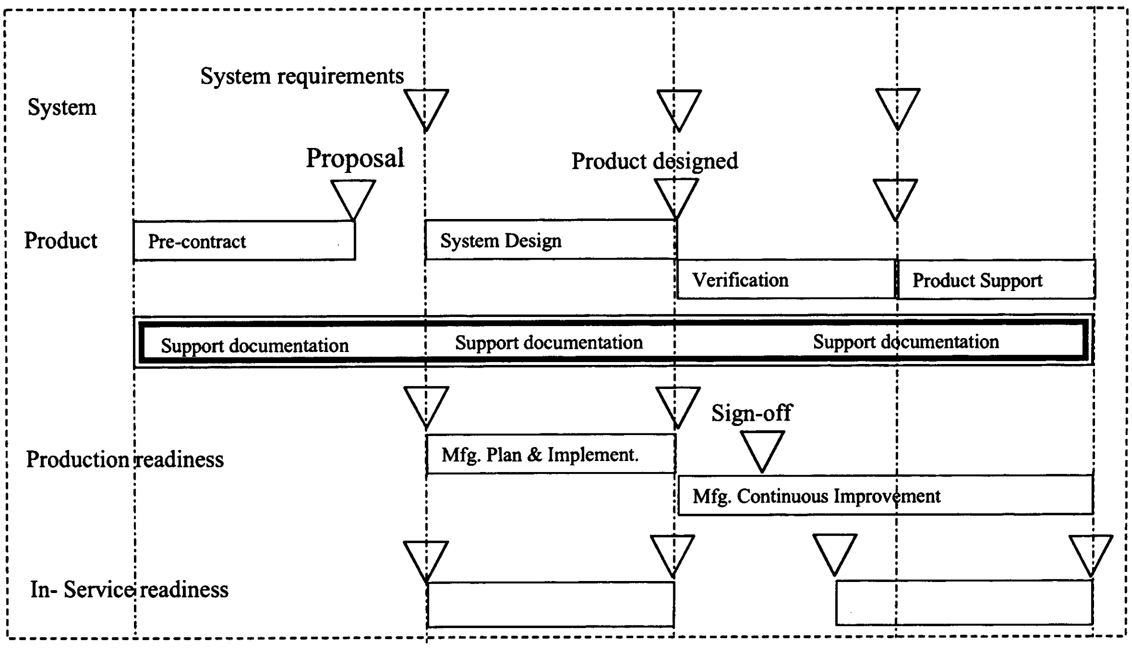

Figure 4-14. "New Product Introduction" process.

The NPI documentation detailed the phases, sub-processes, procedures and reviews (milestones). The information described technical activities to design, engineer, validate, review, and manufacture products and systems.

Engineering Directors owned the NPI process, which had been created after the NPM process. Its purpose was to integrate and standardise many different technical procedures spread across the different sites of the company.

4.3.4 Program management

Program managers led project managers, project team leaders and project teams to achieve program goals. Therefore, program managers had to develop multi-project management skills, business vision and customer relationships. Particularly interesting was that program managers monitored product performance during its life cycle. This task enabled program managers to capture new ideas and breed product innovations. In this sense, a program represented a longer, more stable scenario than a project. One program manager affirmed that he was "the program manager for all the programs of this customer at this company", and another program manager described his role as follows:

> My new role will be responsible for projects to develop these products within Europe, so there's maybe half a dozen project managers that will be reporting to me, so I'll be responsible for that small area of the business.

Project managers and project team leaders were tasked with the development and execution of plans, writing reports, co-ordinating teams and so on. To this end, the company had issued a complete set of documented online PM support, including standard reports and recommended tools and techniques (see the list at the end of this case study).

The company had an extended training program on PM, orientated primarily to program directors, program managers, project managers, and team leaders. There were courses, software-related workshops, professional certification support, and a program to pursue an MSc in PM supported by a local university.

Thus, although PgM was literally the approach to manage new products, the broader MP perspective was observed in program managers' business vision, innovation skills, and post-project extended functions.

4.3.5 Concurrent engineering

CE Understandings

Table 4.6 presents some concepts or definitions expressed by managers and specialists about CE. Some essential characteristics stated by the laymen were similar to those found in the literature; like multidisciplinary collocated teams, meeting customer requirements, parallel working, and the evaluation of all aspects of the product life cycle.

The last comment indicating that "all the different disciplines working concurrently at the same time" confirmed again the confusion introduced in the literature between concurrent and simultaneous thereby making evident that the use of these terms required clarification. The next chapter presents an empirically induced concept with data from the four Companies that pretend to clarify this ambiguity.

Table 4.6. Some concepts of Concurrent Engineering

We've got a number of disciplines from engineering working on different tasks but all going from the same data set, and really just making sure the design evolves in a fashion that is suitable to meet the customer requirements.
Well, my view of concurrent engineering is a simplistic one in that it's doing a number of engineering tasks in parallel, rather than doing them sequentially.
My concept of concurrent engineering is really just making sure that designers and manufacturing engineers, effectively sort of work together, to make sure that the design, a physical part design that is produced is well matched with the capabilities of the manufacturing equipment that is to be used to produce it. It's making sure that engineers and manufacturers work very closely.
My view of concurrent engineering, which is maybe a slightly academic view, is that concurrent engineering is evaluating all aspects of the product life cycle in parallel.
Concurrent engineering is where you have the different disciplines involved in product design which can be different engineering disciplines, but also disciplines such as manufacturing engineering, supply chain management, quality engineering, all the different disciplines working concurrently at the same time, ideally in the same location as part of a collocated team.

The company started CE practices in the early 1990s. One engineering director mentioned that when the company was implementing CAD/CAM systems, software and equipment providers commented that these systems would facilitate concurrent engineering, "at that time we started to say we were doing CE". However, they realised very soon that technology was not enough; people had to be convinced and committed to work together;

> Because if you have people who are separate, who are working in different organisational units with different priorities and they're being measured against different objectives, and even though you're giving them a tool that could allow them to share information, it doesn't make that happen because they have different goals. So you have to give them a shared goal in order to make them really work together as a team.

Besides CAD/CAM systems, the company applied other tools and techniques classified in the literature under the CE umbrella like design and process FMEAs (Failure Mode and Effect Analysis), design for assembly (DFA) and QFD (Quality Function Deployment) (see the complete list at the end of this case study description). However, they were listed in the NPM process manual as "NPM tools and techniques", not precisely as CE tools and techniques which again reveal that the myriad methods grouped around CE in the literature seem to be exaggerated. The researcher then asked managers and specialists about CE tools and techniques and instead of referring to the list of the manual, most of them answered that CE was achieved through the collocated teams and "by improving the communication between the different members in the team and between different teams". The researcher insisted that those tools and techniques listed in the manual had been classified under the CE umbrella in the literature. After some hesitations, managers and specialists admitted that some of them actually facilitated CE. One project manager mentioned that "any tool that helps you to consider all aspects of the design at the same time or as early as possible, facilitates concurrent engineering; project management helps too".

Specialists affirmed that the principles of concurrent engineering were built into the NPI process, or as an engineering director expressed, "the concurrent engineering aspects happen within NPI". In effect, NPI documents described how multifunctional teams operated concurrently. In addition, there was a series of reviews throughout the process, and each review was said to be a multidisciplinary review, making sure that all aspects of the product were considered during the design. At the first stage of the process, manufacturing aspects and the supply chain elements were considered "all the way through, so they're very, very integrated". Thus, in general there was a perception that CE was a way of working, not only a group of techniques (a person mentioned that it was a "philosophy of working").

Collocated teams

Multidisciplinary and collocated teams should approach every program in the company. Members from different functional disciplines like design, manufacturing, supply chain, and quality, were integrated in these teams. The teams were co-ordinated by a team leader, who also performed as a specialist.

The "work-in-team" culture had been promoted in the company for more than 5 years. Perhaps because of this experience people seemed to be satisfied with this way of working. During the interviews there were no complaints regarding authority conflicts or ambiguous responsibilities. High levels of training and shared goals were mentioned as basic ingredients for success.

To some practitioners CE was more or less the same as working through collocated teams[8]. For instance, a project manager described the benefits of collocated teams in the following terms:

> Look, this is concurrent engineering in action. My designer came up with a new concept to be used in our motor. Since we are all very closely located I am going to verify right now with the process engineer about the manufacturability of the concept. Had we been seated in different departments, this process would have taken lots of time.

The following is a list of the most frequently mentioned benefits of CE achieved through collocated teams:

- It allowed shared and therefore better decisions.
- It created project ownership within team members.
- It resulted in a "better job and a tendency to do it quicker".

[8] It should be remembered that this opinion was also shared by academics as seen in Chapter 2.

- "It is not about getting the product earlier, it is about getting the right product earlier".

It should be noted that the last two benefits seem to suggest that better quality is the main advantage of CE followed by reductions in time.

It is also important to comment that despite all the benefits, it was not always possible to staff the teams with the specialists required due to the lack of sufficient skilled resources.

To guarantee cross-team expertise, an independent group of specialists assisted the teams in quality or technology concerns. They looked across all the projects making sure the skills were being developed, and the right quality control was being brought into the tasks. They acted as independent reviewers as well. The same pattern was observed in Company 2 where specialists were in charge of the "cross-fertilisation" of ideas.

4.3.6 Relationship between NPM, NPI, and CE.

The NPM and the NPI processes connection was depicted in a schema showing coincident points along the project life cycle (Figure 4-15). However, people explained this relationship in different terms. The NPM process was defined as a "PGM[9]-owned project management-led, business process to manage the introduction of new products and major modifications". To program and project managers interviewed the NPM process addressed business and PM aspects together, whereas the NPI process included the technical aspects of developing a product. A program manager affirmed:

> So I would say NPM is the way we manage projects, but it is a business methodology in the way that it provides a consistent way of managing projects throughout the business.

It should be noted that the phrase "managing projects" was coincidentally expressed by the program management and has a close connection with the MP broader perspective despite the fact that this perspective was not previously introduced by the researcher.

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[9] Program General Managers

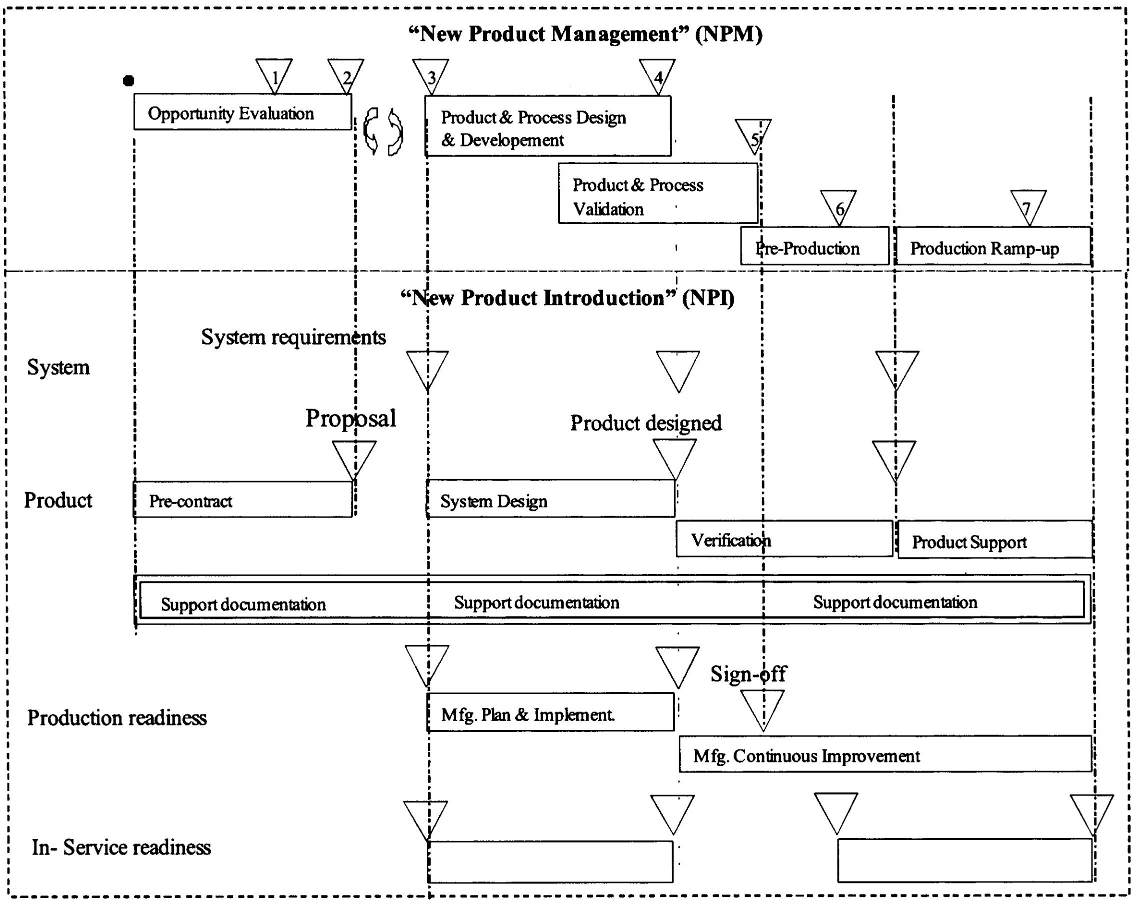

Figure 4-15. Relationship between the NPM and the NPI

According to another program manager, the NPM was a process to add structure across the different company facilities allowing people "to get things done". However, the NPM did not detail the technical road that should be followed, but the NPI did. The latter showed "how we go from a blank piece of paper to a qualified product".

On the other hand, functional heads and specialists considered that the NPM entailed "high level business decisions" and not PM specific issues. These so-called business decisions were described as "whether or not to launch a project and whether or not to continue with a project". These experts considered that the NPI process was about the implementation of the program; making sure that the best practices were included. They mentioned that NPI not only entailed engineering practices, but PM practices and multifunctional processes. An engineering director further clarified this relationship between NPI and PM in the following terms:

> When I use the word engineering processes in regard to NPI, I'm not talking about functional engineering; I'm including design engineering, but also manufacturing engineering, quality engineering, and supply chain management. So it's a multifunctional process of engineering. And this process, the NPI process, does also include the role of the project manager and how projects have to be managed. But to give detail on project management techniques we have a separate handbook.

Apparently the perception of PM was operational since it was about "how projects have to be managed". This concept of the NPI process was similar to PRINCE 2 in case 1 and the IPM or DP in case 2.

Regardless of the different perspectives, the alignment between the two processes illustrated in Figure 4-15 represented an effective framework to include all the technical and managerial decisions. Indeed, each gateway review contained a checklist of activities that should be accomplished. These checklists contained questions embracing all types of activities: project management, business, sales, product quality confidence, and so on.

When discussing the relationship between NPD, CE, and PM with some practitioners, interesting concepts emerged. An engineering director who had been working in the company for a long time mentioned the chronological order in which the different approaches had been implemented:

> What came first was the individual engineering processes that each business had in the past. Then project management was established, with focus on training people in project management techniques, and this is maybe going back 10 years. Then NPM was established, to make sure that the business was investing correctly and that we would have high-level control in our projects. Then we looked at things and said some of our projects are now multi-site, multinational, and we need to make everybody best practice, so then this NPI process was standardised. Concurrent engineering has progressively developed in the last, I would say, 15 years. We've learned how to do it better and better over that period. So multifunctional collocated project teams were really established about 5 years ago.

This chronological set of events resembles those in Company 2, however, a complete comparative view of the implementation order considering the four cases will be addressed in chapter 5.

About the relationship between PM and CE, one program manager affirmed:

> I think the notion of there being some coincidence in the benefits of PM and CE is just that. From my perspective, the two disciplines grew up at different times and for different reasons. However, I think any endeavour aimed at managing an activity of

> outcome is bound to coincide in some way with an approach with similar or overlapping objectives. I think this is where you uncover contradictions when you try to synthesise the thinking. The two disciplines, I think, have been a bit isolationist historically.

The key role of program and project managers in harnessing CE was also emphasised in this company, as it has been done in Company 2. A Sites program manager affirmed:

> You could apply project management as a tool to help deliver a concurrent engineering aspect of an overall project or an overall programme to introduce a new product. I think PM supports any process by helping to put in the proper controls and structures around it.

Some program and project managers explained that CE consisted of developing activities in parallel, arguing that this approach increased the risk of rework and delays. Hence, they applied risk management techniques to minimise adverse consequences. These techniques were specified in their PM methodology. When discussing this topic, another program manager explained that:

> There is a conundrum here which I believe stands full square between CE and PM. CE is concerned with paralleling activities; this inherently introduces duplication, iteration, wasted effort, and program slippage. PM will tend, I believe, to reduce activities to linear strings identifying dependencies, minimising risk and building whatever certainty can be found... I can see no real reason why CE and PM can't be complementary, although I think the secret lies in risk management - understanding the potential quality/time benefits of paralleling, while being able to manage the cost/time risks associated.

Many PM authors share the belief that CE induces risk, as has been seen in chapter 2. However, the risk is mainly associated with parallel development but it was observed that parallel development is only a partial view of CE.

Despite the evidence of the relevant role of the program and project managers in applying CE, the researcher could not identify any specific CE training for program and project managers. The same pattern was observed in Company 2. One program manager was asked why they had not been trained on CE and his answer seemed to justify the goal of this research:

> What I've noticed in all of the companies that I've worked in, is that a lot of companies provide project management courses, a lot of companies provide NPM processes or all that sort of stuff. But concurrent engineering from my experience has

been and still is largely a matter of opinion in most businesses. It's not something that people run courses on, it's not something where I see a consistent level of expectation or understanding, and if it was you probably wouldn't be doing the PhD that you're doing.

Finally, a project manager with more than 25 years of service at the company commented on the need for understanding the relationship between NPD, PM, and CE:

> They were all aimed at solving different problems in industry, so I think really that is the ongoing challenge that we face, is being able to take all of these different things and connect them all together... I think this NPM process is quite a good way of visualising it, but it's a model and that's all it is and I think a lot of it will come down to the individual project and program managers. I wouldn't necessarily divorce any one or two or three elements of it. So the theoretical boys are quite right, they are looking at their own world, but the practical world, that either we've defaulted into unknowingly, or have engineered ourselves into, has actually taken each one of those and pulled it under a kind of single process.

4.3.7 Summary

The NPM was considered by program managers as a program management business-orientated-umbrella process thereby implying that PM broader perspective was in place. Functional managers believed that the NPM was effectively a business process but it did not include PM practices. To them, these practices were embedded into the NPI process "as well as other technical processes" thereby implying that PM was operative (the Pm execution perspective).

Managers' understanding of CE was generally shared and related to parallel development, collocated multi-disciplinary teams and some managers and specialists even affirmed that CE was a way of working and a philosophy. In relationship to PM, two experts affirmed that any tool helping "to consider all aspects of the design at the same time or as early as possible, facilitated concurrent engineering, project management helps too".

An interesting aligning schema was developed that aligned the NPM process and the NPI process. This schema portrayed common review points along the project life cycle. Similar schemas were found in companies 1 and 2.

Program managers were engaged in the development at the middle of stage 1 and were disengaged at the end of the last stage, production ramp up. However, like in Company 2, projects could be extended to provide product service and therefore "in service teams" were integrated led by program managers.

PM was also a professional career within the company. There were training courses for project leaders, project managers, program managers and program directors. Moreover, an MSc on PM was offered in collaboration with a local University.

In general, program managers believed that CE was risky because of parallel working and therefore it was necessary to apply PM-orientated risk analysis tools. Despite the highly intensive PM training program, not any CE training course or workshop was offered. A program manager explained that this was due to the different meanings and expectations that people had about CE.

Resource councils took place where program managers and functional managers negotiated resources. Site Program Managers, who integrated all the resources into one Spreadsheet-like tool, facilitated these negotiations. Although the tool was helpful, much had to be done to improve resource alignment and balancing because, it was said, many operations had to be done manually.

4.3.8 People interviewed by roles

Role	Number
Site Program Manager	2
Program Manager[10]	3
Engineering Director	1
Project Team Leader[11]	1
Project Manager	1
Total	8

[10] Because of organisational changes, one program manager was first interviewed in his role as site program manager reporting to the VP Product and Technology development.

[11] He had been recently nominated as Project Manager, the interview related both roles.

4.3.9 Tools and techniques

The following list contains the tools and techniques mentioned by people or documented in the different manuals reviewed during the case study.

Business and Commercial	**Design, Engineering and Manufacturing**	**Project Management**
- Business model - Decision mapping (customer stakeholders analysis) - Quality Function Deployment	- Design and process FMEA - Safety analysis - Design for Assembly / Manufacturing - Design to cost - Technical risk analysis and management - Value Analysis / Engineering - CAD/CAM/CAE - PDM - Project management - Design procedures - Communication - Target costing	- Project planning - Resource planning - Non technical risk analysis and management - WBS - Gantt Charts - Earned Value Methods - MS Project™ - Responsibility matrix - Customised spreadsheet to consolidate resources. - Communication

4.4 Automotive supplier company

4.4.1 Company and products

The company supplied a variety of custom-made components to the automotive market. This business unit, employing around 250 employees, was first and second tier supplier. Its production system (make-to-order) was driven by new car models or by spare parts batches requested by customers during the car's useful life. As with many car-manufacturer suppliers, this company had to accomplish quality standards like QS 9000 and ISO/TS 16949.

The components produced in the company were an essential part of the automobile vibration system. The number of product sub-assemblies and parts ranged from 5 to 10. The processes to produce them consisted of plastic injection moulding, mechanical assemblies, as well as pre- and post-metal treatment, like phosphating and painting. Compared with the other cases, the products here were relatively simpler.

Roughly, the company was developing between 10 and 18 new products simultaneously. The lead-time to develop was highly dependant on the customer's own lead-time. When a customer required a product urgently, they could design and develop it in as few as three months. In some cases, they were given up to three years to develop a product.

The company did not have a research and development group and therefore, according to the interviewees, the level of product innovation was low. Nevertheless, the product development staff had obtained several patents for innovative products.

As can be seen, there was a clear difference with the other three cases in terms of size, product structure and technology, and the number of projects developed at the same time. Comparatively speaking, developing new products was a relatively simple task and innovation was not as relevant as in the other cases.

4.4.2 New product introduction

The Design, Development and Introduction process

The process to develop new product was described in a manual called "The Management System used in the Design, Development, and Introduction to Production of all new Products" (hereinafter called DDI process), which contained 21 procedures. The DDI process closely adhered to the APQP reference manual (briefly described in chapter 2). So close was this adherence that people used to refer to their process as "the APQP". The DDI stages were outlined in these procedures as follows (for simplicity some detailed steps are omitted):

Stage 1. Receipt and processing of customer request for quotation.

- Raising of sales enquiry form.
- Assessment of strategic implications and resource requirements.
- Specification agreement (establishing customer requirements).
- APQP checklist.

Stage 2. Estimating product costs for customer quotations.

- Concept design proposals (product and process).
- Concept design verification.
- Manufacturing and tooling cost estimates.
- Capital expenditure requirements.
- Quotation to customer.
- APQP checklist.

Stage 3. Prototype phase

- Contract receipt and contract review.
- Program timing plans.
- Product design and process FMEA's.

- Detail design.
- Procurement.
- APQP checklist.

Stage 4. Prototype design validation

- Manufacture of prototype parts.
- Prototype test program.
- Customer validation.
- Product design release.
- APQP checklist.
- Program review.

Stage 5. Pre-production phase I.

- Contract receipt and contract review.
- Program timing plans.
- Process FMEA (review).
- Process and tooling design verification.
- Procurement (tooling and components).
- APQP checklist.

Stage 6. Pre-production phase II.

- Production process validation trials.
- Manufacture of parts for product validation and customer acceptance trials.
- Pre-launch control plan.
- Production acceptance and sign-off.
- Customer validation.

- APQP checklist.

Stage 7. Production launch.

- Authorisation of production start.
- Launch control plan.
- APQP checklist.

Stage 8. Production stabilisation.

- Process monitoring – reduction in variation.
- Improvement opportunities.
- Production control plan.
- APQP checklist.
- Program review.

Program review.

- Review stages.
- Assessment of APQP effectiveness.

This outline reveals that NPD, PM and CE issues were combined in the DDI process. For instance, in stage 1, the Requests for Quotation were analysed to verify if they were in line with a 3-year strategic plan of the company. This plan basically established where the organisation wanted to go as a business. Stage 1 can also be considered part of PM broader perspective. Since program reviews, timing plans, and cost analyses were applied in several stages, it can be said that the Pm execution perspective was permeated in the DDI. As to CE, Technical designs and validation activities, as well as FMEAs were performed.

However, it is important to note that the APQP did not include the business aspects mentioned above; they were added to the DDI by the managers in the company. The Operations Manager stressed this lack in affirming that:

> The APQP process only really picks up a programme once it's been identified as a customer need. Our development process really comes from the business development managers. They'll identify … what products do we need to win new programs in 3, 4, 5 years time.

Although the stages of the process are listed sequentially, stages 3 and 4 were highly iterative. That is, the designs were followed by trial prototypes that confirmed or modified designs. Once a final design met the manufacturing requirements, the prototype validation was executed.

Organisation for the development

Figure 4-16 portrays the organisational structure to develop new products. Program managers co-ordinated the cross-functional teams that designed and developed new products and processes. An executive team was composed of functional heads, the business development managers and the plant manager. This team met periodically (monthly) to evaluate the development of actual products.

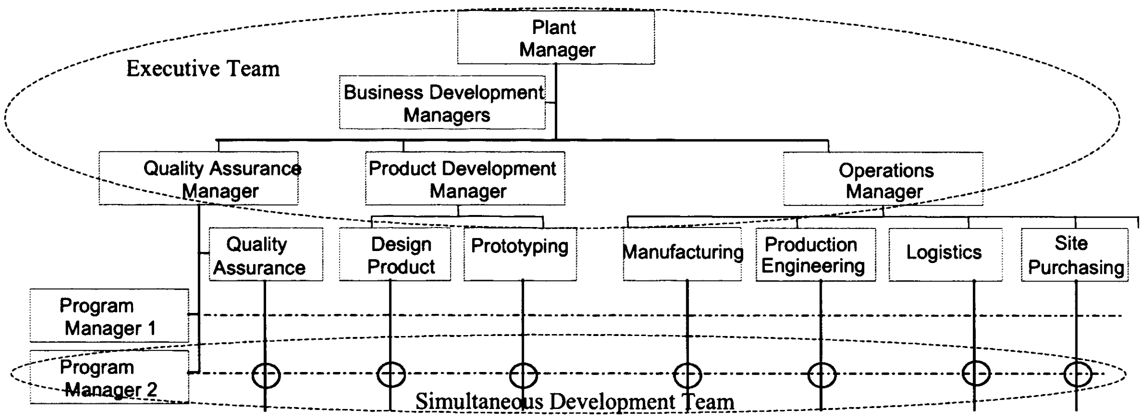

Figure 4-16. Organisation for new product development.

The Business Development Managers were highly involved in the development of new products. They participated in stage 1 to assess whether a request for new products was in line with the 3-year business plan. They also searched for new customers and proposed ideas for new products. One manager commented that business managers were like the "ears and eyes of the customer" because of their commercial knowledge and market awareness. This role resembled the product managers' role described in the case study 1.

Intriguingly, program managers reported to the head of quality assurance. In matrix type organisations, program and project managers normally report to the head of the PM function, except when the matrix organisation is classified as weak. However in weak matrix organisations, project managers (customarily referred to as project co-ordinators) report to functional heads and also perform as specialists, as opposed to full-time program managers as in this company.

People explained that program managers had been reporting to different functional heads along the time. First, they reported to the operations manager, but some problems emerged because "operations had priority". Later they reported to the business development managers but they found that these managers were too busy "going out and winning business". Then it was decided that the Quality Assurance manager would take over the program management function because he had been "a good program manager". Remarkably, managers and program managers seemed to be satisfied with this organisation. They did not seem to be concerned with the lack of a full-time head of program management. It is possible that the volume of new product programs did not require a full-time PM head.

DDI support and resource management

People admitted that there was not much time to plan for improvements, mainly because of a lack of supporting personnel. Thus, the Procedures Manual was only updated when a user prompted an improvement or a correction. The request was then analysed, and if appropriate, it was updated by the Quality Assurance manager.

In general, people believed that the DDI was "a bit bureaucratic". As an example, one manager noted that "the APQP (referring to the DDI) did not help to plan, it is only a tick list". Proposals for improvements were mentioned during the interviews, mainly aimed at diminishing "the lot of paper work". For example, it was proposed that the procedures were stored in an electronic database, whence they could be retrieved and used on-line following the process workflow. This, it was said, would lead to a more proactive application of the quality procedures.

Interviewees mentioned DDI's advantages as well. It was a good quality orientated standard, and a well-focused document (car-business related) that helped "to put structure to our activities". The quality assurance manager affirmed that competitors had similar processes.

Managers were asked whether they made resource capability analyses. They commented that the size of the company and their experience allowed them to make gross estimates and "day-to-day" adjustments based on individual workloads. To cope with the stringent conditions caused by the scarcity of resources, production priorities, and frequent meetings, specialists and managers agreed that developing efficient meetings was more effective than the use of "sophisticated tools" to manage resources. In so doing, program managers were required to be excellent meeting co-ordinators.

Engagement and disengagement of program managers

Program managers were engaged at the end of stage 1: "Receipt and processing of customer request for quotation". Before that, commercial people received requests for quotations from customers and turned to business development managers to verify if the request was in line with the three-years plan. After that, program managers co-ordinated the project teams until the last stage of the process, "Production stabilisation". They should also co-ordinate two "Program Review" meetings, one after prototyping and the other after product stabilisation. The purpose of these meetings was "to assess the effectiveness of the APQP, the performance of the program manager and the simultaneous development teams (SDTs)".

According to the procedures the responsibility of the program manager ceased when production was stabilised, however, one program manager mentioned that the responsibility should end practically with the product's death:

> I take the view that the program manager should not ever be allowed to relinquish responsibility. It's called "cradle to grave"; the program manager loses responsibility for his programs when the vehicle stops being produced or that component is no longer manufactured, because there is a body of knowledge, understanding and experience which really should be maintained.

The business development managers were responsible for monitoring product performance in the market. The product manager spelled out the reasons for this assignment:

> Basically because they can, they act as the eyes and ears of the customer, so they understand what the customer's wants to do out in the market place....They've got a substantial commercial awareness of what's going on with the customer, the product, and the business.

The business development managers had a higher hierarchical position and more prestige than the Program Managers (as in Company 1). Unfortunately, they were not scheduled for interview thereby impeding to acquire a better understanding of their role.

4.4.3 Program management

Unlike the other three companies, the role of the project manager did not exist here, only program managers. The main argument was that programs were so small that they were not subdivided into projects or any other smaller unit. Then, a program manager was asked why programs were not called projects and why program managers were not called project managers. The answer was that, in the motor industry, speaking of programs was more common than speaking of projects. According to the program manager, a program connoted something more repetitive than a project. He considered that in the motor industry when somebody was proposing a project, the meaning was bound to something "experimental". On the other hand, a program "had come to mean taking products from concept into production, in a structured way".

The company did not have plans for program management training. Program managers and team members were trained "as required", but none of them had taken a PM course or workshop. Perhaps because of this, program managers were not applying an extensive set of PM tools (see the list of tools and techniques at the end of the case study description), or at least not as extensively as in the other cases. However, nobody expressed the need for training to program managers. One program manager mentioned that he only had to be cognisant of the DDI process and how to achieve people's commitment. Another program manager simply answered that:

> I've picked up techniques of program management in my previous job, not formally training programs though... not directly, it is more ten years of experience as opposed to - you know, actually doing it on a day-to-day basis.

4.4.4 Concurrent engineering

CE Understandings

Four out of nine persons interviewed did not acknowledge the term "concurrent engineering". The people acknowledging the term expressed their understanding as reported in Table 4.7. As can be seen, people's understanding of CE did not differ much from the concepts appearing in the literature: teamwork, parallel development and early involvement. Unlike the other two cases where quality was emphasized as one of the main CE benefits, practitioners in this company highlighted the reduction of the projects' lead-times.

The following CE practices were identified (see at the end of this case study for a complete list):

- Design and process FMEA's.
- Design for Manufacture.
- CAD Systems.
- Multidisciplinary teams.

Table 4.7. Different understandings of concurrent engineering.

Working together, as a team of different skill sets, trying to bring not just a customer requirement, but manufacturing requirements, program requirements, business requirements, all together.
Concurrent engineering is, rather than things happening in individual steps, you're trying to do things in parallel, so that you can shorten lead-times, and move things along.
A number of people work on the same project, or the same product, at the same time...the idea is everyone looking at it concurrently, and therefore you're able to squeeze the time scale down a great deal.
I think it is the same as simultaneous engineering, you do things together. You don't design it, throw it to prototype, prototype to process. You use simultaneous activities, concurrent activities to actually make sure that everybody knows what's going on and everybody has an input.
Each speciality in terms of engineering, design or process should be involved as early as possible in order to shorten the time from concept to delivery and also to improve that process. So the designers come up with something that cannot be manufactured, or the manufacturing people come up with a piece of equipment that won't fit through the doors.

When people were asked how the company was applying CE, the most common answer was "through simultaneous development teams" and one manager mentioned that the APQP enabled it.

Some managers commented that the company still had to improve these practices. For instance, one specialist was concerned about the lack of a shared product data management (PDM) system. Although designers were using CAD/CAE systems, manufacturing engineers could not access the information online. However, people argued that the size of the company and the corresponding business profits could not justify the use of such electronic systems.

Another program manager mentioned that teams were working together but not necessarily approaching the activities simultaneously. This last observation was considered important but before discussing it further, it is necessary to first explain the functioning of the simultaneous development teams.

Simultaneous development teams (SDTs)

Multidisciplinary and cross-functional teams coordinated by program managers (see Figure 4-16) designed and developed the new products. Members of these teams were not collocated; they remained physically in their respective functional department. Team members worked part-time in programs and participated in several programs at the same time. The teams were not considered autonomous since functional heads kept authority over the team members.

The basic *modus operandi* consisted of weekly meetings. During the meetings, any member of the team could raise ideas for improvement or discuss the difficulties arising while developing a current product. Propositions were then discussed between the team members and whenever changes were carried out the modifications were presented at the next meeting.

Ideally, all the team members should attend the meetings but managers and specialists commented that different priorities and the scarcity of resources constrained participation. Program managers mentioned that they expected at least the presence of the specialists involved in the phase being developed. For instance, during design, designers and prototype specialists assisted regularly, yet production people rarely did. At the opposite end of the development, during product launch, production and manufacturing specialists assisted regularly, and designers less frequently. Table 4.8 illustrates the typical pattern of assistance. It should be noted that this pattern does not assure early involvement in design, since people responsible for the last stages, like tooling and production, did not participate until late in the development. The ideal case would have been the attendance of all members to the first stages or at least to the design stage.

Table 4.8. Functional representation at SDTs meetings.

Function represented	Quoting	Designing	Prototyping	Tooling	Production
Design	✓	✓			
Purchase	✓	✓	✓		
Prototyping		✓	✓	✓	
Manufacturing			✓	✓	✓
Production				✓	✓
Program management	✓	✓	✓	✓	✓
Business development	✓				

Team members, program managers and functional managers were satisfied with the effectiveness of the teams. Although team members were not collocated, the meetings and the co-ordination of the program managers made them aware of the current developments. Thus, when every member started his or her activities, there was little room for surprises. As one manager stated, "at least we know why decisions have been taken as they have". Moreover, the functional managers had to sign-off specific results throughout the development, reinforcing mutual understanding.

However, specialists admitted to not starting activities before the previous ones ended (except when contingencies arose that forced the schedule to be compressed). Hence, the simultaneous development teams were not working on the activities simultaneously despite the team's label: Simultaneous Development Teams. One program manager accepted that this observation was generally correct. According to him, some specialists did not want to start work in advance because of the risk of making mistakes. He added that this "risk-averse culture could be changed by training people in risk management".

The dependency on customer's project life cycle was a frequent headache for the crew. The team made plans to develop a product according to customer requirements but these changed very frequently. Obviously, these changes forced negotiations, but in order to retain customers, the teams had to re-plan and speed up the development. The product development crew could react quickly and stay competitive because the small size of the company avoided intermediate channels and bureaucracy. However, they regretted that this customer cycle-time dependency made them less able to breed innovative solutions.

From Customer Focused Teams to Simultaneous Development Teams

Before being organised in SDTs, the development of new products was based on collocated teams called “Customer Focused Teams” (CFTs). Each collocated team attended to specific customers. The general operating characteristics of these teams were:

- Full time assignment of team members.
- Complete responsibility over the programs
- The leading role was titled “project leader” and often this responsibility rested with a skilled designer.

However, this organisation had been changed because several constraints emerged, among them:

- Teams were working as islands.
- There was little technology exchange between teams.
- Lack of engineering standardisation.
- Teams became “resource hungry”.
- “If the customer stood still, the teams had to”

Persons who had been working in both types of teams felt the SDTs to be more resource efficient and more effective in terms of engineering solutions. One manager commented that evidently some customers preferred the CFTs. This transition was interesting when compared with the three previous cases where two companies worked with collocated teams and the third company promoted this method. Cusumano and Nobeoka (1998) have also commented that co-location tends to inhibit the development of technology and the cross-fertilisation of ideas.

4.4.5 Relationship between DDI, CE, and PM

The "Product Quality Timing Plan" required program managers to issue regular reports "to ensure that senior management were aware of project issues and risks". This executive awareness is a characteristic of well-established NPD practices. The template to make the reports included project risks, a milestone chart, the APQP requirements, a cost description area, and the SDT members. Thus, the template was a good example of how the company tracked NPD, PM and CE activities in product development. Likewise, check-lists were generated at the end of each stage, as in the third case study.

The head of program managers emphasised that program managers and the APQP process were fundamental components in achieving concurrency. A program manager revealed his way of achieving concurrency: "...and my role there was to force them, against their natural inclination, to work together, rather than blaming each other. And I think it's a better way of working."

The relationship was explained by a program manager in the following terms:

> Here we work within much formalised Advanced Product Quality Planning procedures Based originally on the requirements of QS9000. We are now working to ISO TS16949 standards against which we are audited twice a year. The three approaches that you describe in your outline[12] are all integrated into our procedures - but work to a greater or lesser level of effectiveness.

The APQP was said to have been implemented since 1997 (five years before the case study) by a technical manager who "put together a thorough process". However, the company had been using program managers and cross-functional teams since the last 10 years. Hence, probably the APQP was implemented to integrate the teamwork, program management, and technical processes as well. Nevertheless, it is also possible that it had been implemented for the sole reason of accomplishing automotive standards. Unfortunately the people interviewed did not know details of the APQP implementation process.

[12] The three approaches referred in the access letter were NPD, PM, and CE.

These relationships and assumptions, as well as the evidence gathered along this case study, suggest that the APQP is a practical guide to develop new products including PM and CE elements and to minor extent NPD elements. However, the mechanistic nature of this approach seems to make it less suitable for more innovative projects.

4.4.6 Summary

The APQP, through the DDI process, was being followed in this company to approaching the development of new products. Managers commented that it was a well-developed standard focused on the automobile industry. Nevertheless, the lack of strategic aspects included in the APQP compelled personnel to complement the DDI process with additional steps to ensure that projects are linked to business strategies. Additionally, the standard was generally qualified as "a bit" bureaucratic. In any case, it was confirmed that CE, NPD, and PM characteristics were incorporated into the APQP.

Not all interviewees acknowledged the term CE despite that they were practicing it to some extent (multidisciplinary teams, FMEA, Design for Manufacturing). Others related the term with parallel development and work-in-team. One manager stated that "CE was embedded in the APQP" and other that CE was being applied through the simultaneous development teams.

Program management was practiced in the company before the adherence to the APQP. Later, customer focused teams were implemented to developing new products. At the time the case study was developed, these CFTs had been again replaced by simultaneous development teams which were less autonomous than the formers. It is then speculated that PM was first in place, then the company started to work in teams and developing CE practices and finally the APQP was implemented.

Program managers led product development. They were engaged at the end of stage 1, and handed over the project after product stabilisation. Unlike the other three companies, program managers in this company did not lead group of projects nor project managers. Therefore, it could be said that they acted as the project managers in the other companies. In this company the term project was rather related to a one-of-a-kind project, something more "experimental". A program manager said that this was the meaning of the term project in the automobile industry.

Business managers played an outstanding role in developing new products setting strategies and assessing the alignment between business goals and new product development. So, in this sense they were like product managers in the first company or business managers in the second and third companies. Although the term product manager existed in the company, the role was technical, like a chief engineer, and not commercial.

Resource assignment and balancing was handled by making gross estimates and day-to-day assignments without using any specific tool. Despite the stringent working conditions due to personnel scarcity, it was said that the size of the company did not justify a "sophisticated" tool for resource assignment and balancing.

Finally, unlike the other three companies, PM was not considered as a professional career here. The company did not have any PM training program and program managers had not taken any PM course elsewhere. Moreover, there was not a hierarchical ladder to ascend, due to the lack of a head of program management position. The head of program managers was the head of Quality Assurance. Clearly, the PM approach followed was based on a Pm execution perspective. The business development managers, and not program managers, were executing some of the business-orientated tasks associated to a PM broader perspective.

4.4.7 People interviewed by roles

Role	Number
Product development manager	1
Program manager	2
Prototype and validation team leader	1
Purchase manager	1
Mould process and development manager	1
Lead engineer	1
Quality manager	1
Operations manager	1
Total	9

4.4.8 Tools and techniques

The following list contains the tools and techniques mentioned by people or documented in the different manuals reviewed during the case study.

Business and Commercial	**Engineering and manufacturing**	**Project Management**
- Three year business plan	- APQP - Design FMEA - CAD Systems	- MS Project™ - Gantt and milestone charts - Critical Path Methods - Tracking Gantt

Chapter 5 Cross-case analysis

In this chapter the empirical data arising from the four case-studies are compared and analysed searching for cross-case patterns (similarities and differences). Concepts emerging from the comparison are presented, analysed and explained. The conceptual categories or dimensions emerged from the data, pre-established theory, initial frameworks (Eisenhardt, 1989) or some times "by inspiration" (Langley, 1999).

5.1 Types of companies and characteristics of their products

Table 5-1 shows the main characteristics of the companies and their products or services. In general, companies 1 and 4 were relatively different to each other while also differing from Companies 2 and 3. These last two companies were relatively similar to each other.

The difference in the forces driving the development may be an indication that, firstly, the pressure to launch products on time could have been higher in Company 1 because being first-to-market was vital. In Companies 2 to 4, time was important during the bidding process, however, once a contract had been awarded, product reliability became the highest priority since the safety of human lives came to the fore. Secondly, in Company 1 the process to select and develop new products was continually assessed to verify that the original market needs had not changed. The size of Company 4 was relatively small when compared to the other three companies.

Figure 5-1 illustrates the type of new products developed by the companies in terms of complexity and newness. This characterisation was based on the frameworks proposed by Clark and Fujimoto (1991) and Griffin (1997a) which were mentioned in Ch. 2.

Table 5-1. Companies and the characteristics of their product

Issue	Company 1	Company 2	Company 3	Company 4
Sector	Services, telecommunications	Manufacturing, aeronautic	Manufacturing, aeronautic	Manufacturing, automotive
Product	Voice, text, and image transmission	Engines	Power and control systems	Assembled parts
Position in the supply chain	Service provider to end consumers	First tier (business-to-business)	First and second tier (business-to-business)	First and second tier (business-to-business)
Number of employees (Aprox.)	9000	2000	2000	250
Production type and volume	Make to consume	Make to order, batch between 10 and 200 engines	Make to order, around 200 kits per order	Make to order, thousands of assembled parts per batch.
Main forces driven the development	Market-driven	Contract-driven	Contract-driven	Contract-driven
Number of projects at the same time.	Approximately 80	*Approximately 140	More than 30	Approx. 7
Lead-time to develop	40 days to one year	5 – 8 years	1 – 2 years	5 – 8 months

* Including both new product projects and existing product production orders

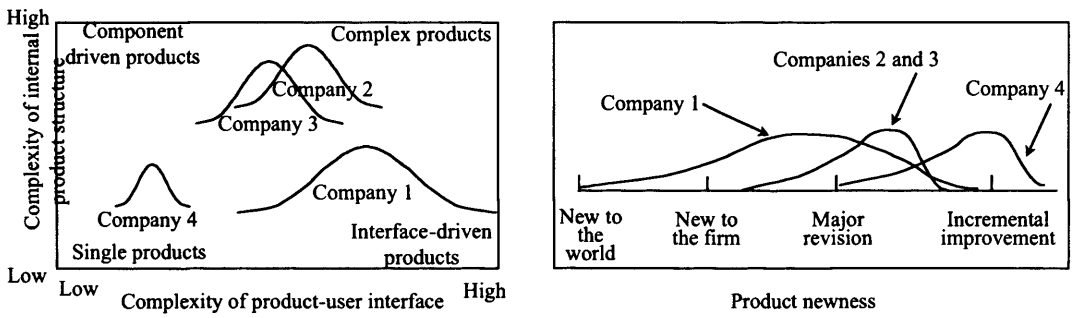

Figure 5-1. General characterisation of products by complexity[1] (after Clark and Fujimoto, 1991) and by product newness (after Griffin, 1997).

[1] Complexity is evaluated by internal product structure, and product-user interface. Product internal structure refers to the number of distinct components, production steps, number of interfaces, and technological difficulty of and severity of the trade-offs among different components. Product user-

In general, both product complexity and newness were remarkably similar in Companies 2 and 3. The products from Company 4 had a relatively low level of complexity and product newness. Considerable variation occurred in the products of Company 1 where some of them represented the highest levels of complexity and innovation, but many others were developed to add some features to current products.

5.2 Understanding Concurrent Engineering

5.2.1 Cross-case general findings

Table 5-1 shows the main findings related to CE understandings and practices applied in the four companies. CE practices were being applied in Companies 1 and 4 despite the fact that the majority of respondents in Company 1 and four persons in Company 4 ignored the term. This is evidence that CE is still an approach that is difficult to recognise by practitioners. Most practitioners related CE with teamwork but not necessarily with co-location (Company 4). The concept of CE varied considerably in the four case studies where CE practices were observed, but they had not been launched as a part of a company-wide CE initiative, not even in Companies 2 and 3, truly leaders on CE practices application. Unlike PM and NPD, there was no evidence of CE manuals, procedures or workshops where the companies could have fostered a unified understanding and enhanced commitment towards this approach. It should also be remembered that practitioners in Company 2 and 3 did not relate tools like, QFD, FMEA, CAD/CAM/CAE and PDM systems to CE. In fact, the only evidence that QFD was being applied was in Company 3 where it was classified in manuals as a "business and commercial tool". In two companies (1 and 2) the term concurrent was used to define CE, a circular definition also observed in the literature.

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interface is related to the number and specificity of performance criteria, importance of measurable versus subtle and equivocal dimensions, and holistic versus narrow criteria.

Table 5-2. Main findings about CE understandings across companies

Issue	Case 1	Case 2	Case 3	Case 4
Interviewees acknowledging the term	3 out of 14	All	All	5 out of 9
CE main understandings	Concurrency, design and development across countries, and co-location	Early involvement in design, parallel working and concurrency	Multidisciplinary collocated teams, meeting customer requirements, parallel working, and the evaluation of all aspects of the product life cycle	Teamwork, parallel development and early involvement
Had the company launched a CE initiative?	No	No	No	No
Main practices observed	Teamwork, co-location, early involvement in design, product data management.	DFM, DFA, CAD/CAM systems, multidisciplinary teams, co-location, early involvement in design, parallel development[1], product data management	DFM, DFA, CAD/CAM systems, multidisciplinary teams, co-location, early involvement in design, parallel development[2], product data management	DFM, CAD systems, multidisciplinary teams
Main benefits	Not Applicable[3]	Less rework and time compression	"Better job and a tendency to do it quicker"	Less rework through shared decisions

1 - Through the use of Design Structure Matrices and workflows.
2 - "Parallel development is embedded in our NPM process"
3 - Practitioners believed that they were not practicing CE

5.2.2 Analysing in detail how CE was applied

When comparing practitioners' understandings of CE in the four companies (presented in Ch. 4), the following common and fundamental characteristics emerged:

- "All disciplines working concurrently at the same time"
- Doing things in parallel
- Work-in-team
- Gradual release of information
- Evaluating all aspects of the product life cycle
- Early involvement

These characteristics were analysed in detail based on the data gathered in the field and are explained in the next sections.

5.2.2.1 "All disciplines working concurrently at the same time"

This phrase drew particular attention since "concurrently" and "at the same time" are very similar concepts if not the same. A definition from the dictionary confirms this appreciation:

Concurrent: Happening at the same time as something else[2]

As a matter of fact, redundancy should not be a surprise since many academics and practitioners understand concurrency as "doing things in parallel" (see Ch. 2). Nevertheless, concurrent has another meaning that is worth highlighting:

Concurrent: Meeting or tending to meet at the same point; *convergent*[3](italics added).

This alternative meaning spawned the idea of temporarily substituting the term "concurrent" with the term "convergent" to avoid redundancy. *Convergent*, according to the dictionary definition above means "meeting or tending to meet at the same point". Another definition of *convergent* is "tending to one point of focus"[4]. Hence, the phrase "all disciplines working concurrently at the same time" could be re-phrased using the term convergence: "all disciplines converging or meeting to one point and working at the same time". The redundancy happens to disappear as converging or meeting is relatively different to working at the same time or in parallel.

Four different forms of convergence were observed in the companies: meetings, co-location, on-line information, and public boards (Figure 5-2). Firstly, in all four companies, multidisciplinary teams converged or met to work together either as collocated teams (in Companies 1, 2, and 3) or in meeting rooms (in Companies 1 and 4). Besides, Companies 1, 2, and 3 used different tools to converge with on-line information, such as instructions appearing on Intranets. Several program and project managers showed the typical "war rooms" with boards hanging on walls, containing project

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[2] *The American Heritage® Dictionary of the English Language, Fourth Edition, 2000.*

[3] *The American Heritage® Dictionary of the English Language, Fourth Edition*

[4] *Webster's Revised Unabridged Dictionary, © 1996, 1998 MICRA, Inc.*

information to all team members and project stakeholders. On these walls were Gantt charts, design sketches, product breakdown structures and so on. These boards were visual instruments to converge on information as well.

Regardless of the form of convergence, the goal was the same: to share information in order to expedite decision-making.

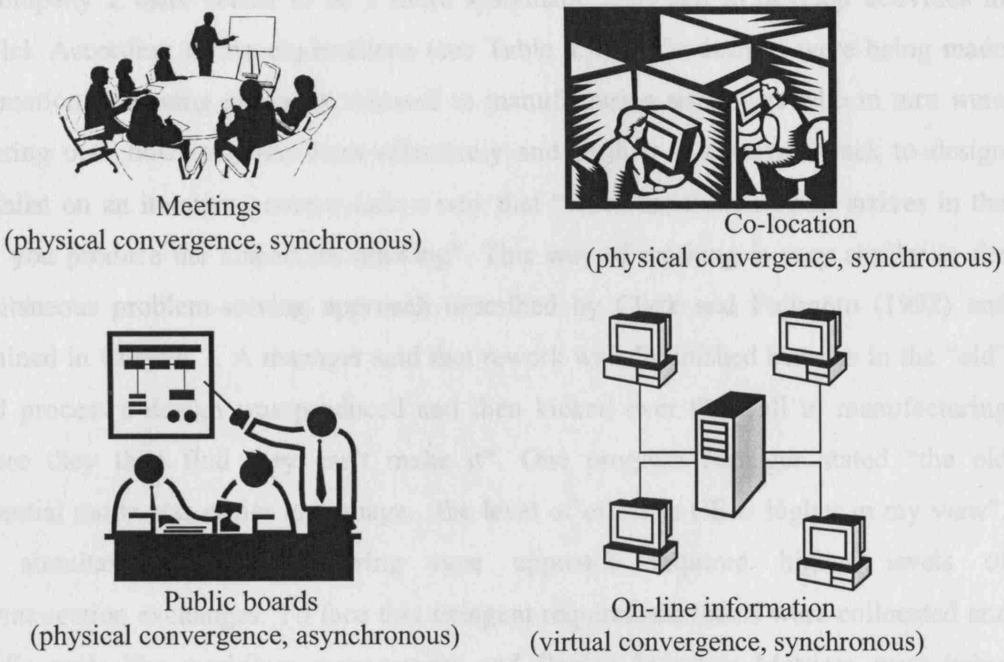

Figure 5-2. Four means of convergence

5.2.2.2 Doing things in parallel and the risk of rework

Practitioners in the four companies mentioned parallel development as one of the most fundamental characteristics of CE which was generally understood as initiating downstream activities before finishing upstream activities. However, while the concept was commonly understood the level of application of this practice varied as well as the perception of the associated risk.

In Company 1 the stage gate process limited the possibilities for developing the stages in parallel since business gates represented go no-go decisions, above all milestone 3. However, when the pressure to introduce new products was considerable managers started stages before the evaluation of the business gates in order to gain time to market.

In these "exceptional" cases the review body was informed and program managers were instructed to consider the associated actions to prevent risks. This trade-off between control through gates and parallel development to reduce time-to-market is still a research topic where the use of flexible gates has been proposed as one possible solution (see section 2.2.5).

In Company 2 there seems to be a more systematic approach to develop activities in parallel. According to the explanations (see Table 4.5) while designs were being made information was being gradually released to manufacturing specialists who in turn were "figuring out" how to make them effectively and feeding information back to design specialist on an iterative process such a way that "when the finished part arrives in the store you produce the inspection drawing". This way of working is very similar to the simultaneous problem-solving approach described by Clark and Fujimoto (1992) and explained in Chapter 2. A manager said that rework was diminished because in the "old" serial process a design was produced and then kicked over the wall to manufacturing "where they then find they can't make it". One program manager stated "the old sequential mode was easier to manage…the level of effort in CE is higher in my view". The simultaneous problem-solving type approach required higher levels of communication exchanges. To face this stringent requirement teams were collocated and specific tools like workflow management and Design Structure Matrices were being applied.

In general, managers interviewed from company 2 perceived the simultaneous problem-solving approach less risky than the serial one in terms of rework. The only contrasting evidence was found in a program management manual where it was recommended to enter in a new phase only when its predecessor was complete since "it is universal experience that failure to complete each stage sharply increases rework, delay and costs".

The NPM business process in Company 3 showed overlapped phases, however, there was a general perception between program and project managers that parallel development was a risky strategy. A program manager stressed that overlapping "inherently introduces duplication, iteration, wasted effort, and program slippage". He believed that PM tends to minimize these risks through risk management, which consists basically of "understanding the potential quality/time benefits of paralleling, while being able to manage the cost/time risks associated".

In Company 4 parallel development was also mentioned as one particular characteristic of CE and although the simultaneous development teams were supposed to approach activities simultaneously they were rather working serially. A program manager mentioned that specialists did not want to start activities before the previous one ended because of the risk of making mistakes. He then mentioned that people should be trained in risk management to overcome this "risk averse" culture.

Despite the generalized notion that parallel development was a necessary ingredient to reduce the project duration, program and project managers from Companies 1, 3, and 4 associated this strategy to risk and recommended the use of risk management. In Company 2, on the other hand, there was a perception that parallel development or the simultaneous problem-solving of activities reduced the risk of rework whereas the sequential activities increased this risk because of the "over-the-wall" syndrome.

In order to gather additional evidence about the risks of rework in relationship to CE, the research interview transcripts and documents were reviewed and Table 5-3 presents the most relevant comments. In general practitioners were confident that their CE practices (not specifically parallel development) tended to reduce the development time, to involve less risk and to bring about better quality products. Even the companies that were not systematically developing activities in parallel (1, 3, and 4) reported gains in lead-times because rework was diminished by approaching the projects through integrated program (or collocated) teams or simultaneous development teams. In fact, most practitioners mentioned that the benefits of CE were primarily orientated at improving the quality of the product, rather than reducing the lead-time. Unlike many reports appearing in the literature, no one person interviewed explicitly mentioned cost reduction as a benefit of CE although rework reduction generally leads to cost reduction.

In this case the physical convergence allowed the team members to quickly verify design concepts and the project managers can ask the manufacturing engineer to start the manufacturing process. Therefore, convergence (physical in this case) facilitated parallel development, but the project manager played an important role in triggering it. An engineering director from Company 2 confirmed this role in the following terms:

> The tool, in theory, that enables concurrent engineering to work effectively, is having good project management by saying 'this is the task that I now want you to do because the information is at a level where that task can be done effectively'.

Table 5-3. Comments about the risk of rework in relationship to CE.

CE brings about less rework and it shortens the lead-time. (Chief Engineering, Company 2)
You don't have to do it all again. (Specialist, Company 2)
Concurrent engineering is not just about getting a product earlier, it's about getting the right product earlier. (Specialists, Company 3)
At least you get a better understanding of why decisions have been made as they have (product manager, Company 4).
I would say that having a cross-functional team, or simultaneous team or whatever, it does make the outcome more reliable, and I would suggest that it is both in terms of the quality of the outcome as well as the time of the outcome is better. And there is less risk. (Specialists, Company 4)

Likewise, a program manager from Company 4 appointed that his role was "...to force them (the team members), against their natural inclination, to work together, rather than blaming each other". Hence, a program or project manager may foster or inhibit parallel development thereby confirming the cause-effect relationship proposed by Koufteros *et al* (2002) between PM and CE.

5.2.2.3 Work-in-team

A common pattern was observed in all four cases: the development of new products was entrusted to teams. All of the interviewees and many of the internal documents consulted highlighted the importance of working as a team to achieve better results. Working as a team or *work-in-team* implied that the members of multidisciplinary groups worked together in pursuing a common goal. Many managers and specialists within the four companies agreed on the relevant aspects that characterise effective work-in-team, amongst others, multidisciplinary problem-solving, common goals, commitment, collaboration, and good levels of communication.

To some practitioners (and academics, as reported in chapter 2) work-in-team meant practising concurrent engineering. For instance, a question frequently asked to interviewees was how does the company apply CE? In many cases the answer was relatively similar, "through the teams". When a manager in Company 4 was asked whether the company had started a program to implement CE, he answered, "not specifically, but that's what APQP and multidisciplinary teams is all about". However, work-in-team should not be viewed as CE, but as a constituent or a conceptual category of CE. This distinction is important in understanding the essence of this approach and to avoid confusion between terms.

Work-in-team is related to convergence (another conceptual category of CE) but they are not the same thing. The teams in the companies converged when they were collocated or participated in meetings; however, this convergence did not necessarily bring about the work-in-team. For instance, a CAD/CAM system had been implemented in Company 3 which improved convergence on information. However, the results in terms of productivity were not as good as expected, as the teams did not share the same goals and beliefs (a basic ingredient for a successful work-in-team).

Working-in-team does not necessarily imply bringing about parallel development as happens to be the opinion of a number of authors (see chapter 2). Data confirming this insight was particularly clear in Company 1 where teams could not start detail design (stage 4) before finishing the proposal (stage 3). Another example can be drawn from Company 4 where multidisciplinary teams met weekly to discuss product development issues. After the meeting, however, people did not start working until the previous work had been released and signed off. Commenting on this aspect with a program manager, he said that in general "there is a tendency within this organisation to work as a team, sequentially". In Company 2, although the work-in-team was paramount, an engineering director remarked that "you could still have an IPT ("Integrated Program Team") and operate sequentially or serially".

5.2.2.4 Gradual release of information

The following explanation given by a project manager helps to describe this concept:

> So for instance, you might ask the supplier to come into the company to discuss the actual design you want to undertake a lot earlier in the process than you would normally. By bringing them into the discussion very early on, you can evolve the design much more generically to their capabilities, if you like. And that would involve releasing drawings on an iterative basis, so you might issue prelim drawings that they can work on, and use this to formulate their costs or tooling that they may need. So there is a progressive release of the drawings, if you like.

Thus, by "gradual" it is understood "progressive" or "not in one shot" while "release of information" means producing and sharing information.

Convergence is a concept equivalent to release of information if it is analysed from a different position. For instance, the release of information from designers to suppliers can be viewed as suppliers converging on the information released by the designers. Hence, in this conceptual framework release of information is a conceptual category of convergence and, therefore, it can be said that earlier convergence on information tends to improve product development. However, for this to happen, it is necessary to create an appropriate climate to work-in-team. A head of purchasing put it in the following terms:

> Yes, with our big suppliers we have very good relationships. I actually sent some drawings, as you've just described, this morning. And what it means is if I can send out preliminary drawings, then they can start to put together a process and a quotation of how they would produce that part. This speeds the whole process up. It means that they can be talking to our design engineers, whilst our design engineers are doing a final drawing, which is very, very useful, because our suppliers can then advise our design engineers on how we can make the part better.

5.2.2.5 Evaluating all aspects of the product life cycle

A program manager explained this concept as follows:

> I think if we were all doing it properly, we would have things like decommissioning, disposal or recyclability of the equipment brought more up-front into the design... We'd have a lot more support form, you know, health and safety, quality and a lot of the more downstream sort of disciplines."

This description implies that all valuable information from the different stages of the product life cycle should converge to product design. In fact, techniques like Design for Manufacturing (DFM) and Design for Assembly (DFA) match this concept. These techniques consist of designing products with ease of manufacture and assembly in mind. An extended concept is design for "x" (DFX), where "x" means design for anything: ease of use, design for maintenance, design for recycle and so on. Therefore, to achieve DFM, manufacturing engineers collect, classify, standardise, and save manufacturing and assembly rules or guidelines into databases so that they can be retrieved by design engineers when making decisions (Molina et al, 2001). These rules or guidelines contain, in essence, knowledge learned by practitioners which can also be shared through meetings or consultation.

Accordingly, the upstream functions, such as designers, converge to the explicit knowledge shared by the downstream functions, such as process engineers, manufacturing engineers and so on. A different mode of convergence occurs during the early release of information. In this case, downstream functions, e.g., the suppliers, converge to upstream information, e.g., designers' information. It becomes a sort of two-way or *bidirectional* convergence (Figure 5-3).

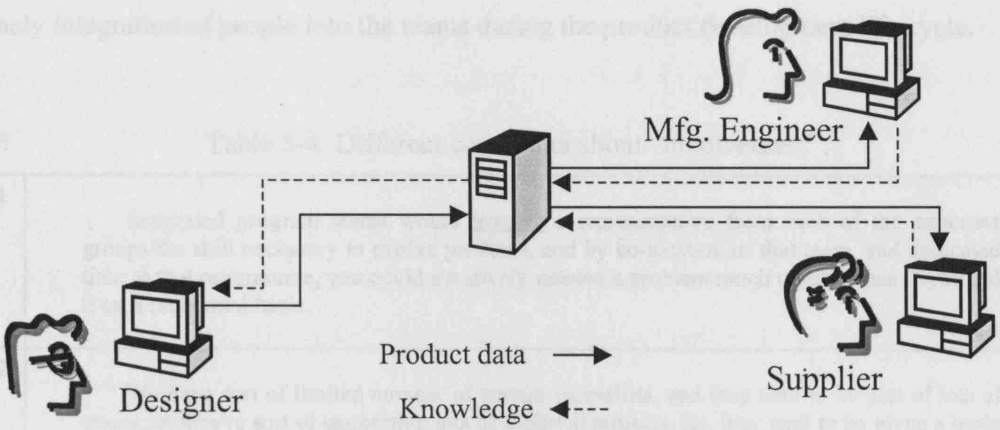

Figure 5-3. *Bidirectional* convergence of product data and knowledge

A good example of bidirectional convergence is described in Dodgson et al's (2004) account of the Bilbao Guggenheim Museum design and construction:

> It showed how shared databases could be used as an essential tool in new integrated design and production processes, by different specialists located in different countries. The result placed the designer within the team at the centre of the process, enabling better value to be provided to clients. The designers' responsibilities were increased because they generated the database to which everyone else worked. At the same time, the design office was placed in closer relationships with contractors, suppliers and subcontractors. (Dodgson et al, 2004: 10).

5.2.2.6 Early involvement

One manager from Company 4 commented that in applying CE "each speciality is involved as early as possible". He continued to explain that by "involved" he meant "included" or "integrated", that is, each team member representing each of the different disciplines should be integrated into the teams as early as possible.

To ensure a proper understanding, the meaning of "involved" or "involvement" was checked in all interview transcripts from Companies 2, 3, and 4. The term was overused:

it appeared in 152 text units across the manuscripts of the interviews. Table 5-4 shows selected comments illustrating different understandings.

The first comment confirms that "involved" can be understood as "integrated" or "included". In this sense, "early" or "late" involvement should be understood as the timely integration of people into the teams during the product development life cycle.

Table 5-4. Different comments about "involvement".

1	Integrated program teams would <u>involve</u> a representative from each of the expertise groups the skill necessary to evolve products, and by co-location of that team, and dedicated time to that programme, you could iteratively resolve a problem much quicker than if you did it on a sequential basis.
2	We have sort of limited number of certain specialists, and they tend to be part of lots of teams, so they're sort of supporting lots of different projects. So, they tend to be given a basic piece of work and they'll do that piece of work, they'll hand it back and they'll move on to the next one, so they don't tend to be quite so <u>involved</u> in the team.
3	I am aware of the design but not specifically <u>involved</u> because my element would be probably to provide advice for specific technical elements.
4	They (vice presidents) were heavily <u>involved</u> during the first stages, you know, the initial bid proposal negotiation. Then they sort of step back and let the project team get on with designing
5	It's the fact, that people are within a project team now, they're not in a function, so for a start they feel more ownership for the project, and also that they can see how they fit into the success of the project, so they feel more <u>involved</u> and more committed."

By analysing comments 2, 3 and 4, a different understanding of "involved" seems to arise. For instance, the second comment refers to scarce specialists who had to support many different teams. Because of this multi-tasking job they had to be "aware" of the problems being solved by the teams, rather than "specifically involved". This awareness was acquired in meetings or through written communication, such as memos and e-mails. The fourth comment includes the expression "heavily involved", which meant that the company vice presidents had assigned a great deal of their time in designing the stages 1 to 3, and less time afterwards.

Therefore, in the two latter cases (scarce specialists and executives), the concept of involvement was understood as the time assigned to specific tasks not precisely as the timely incorporation of the teams.

According to these understandings, involvement may have two conceptual dimensions: early-late and heavy-light. For instance, a team member can be engaged early in product development yet he or she can be lightly involved (partial time), like the scarce specialists. By contrast, a team member can be engaged later in product development, yet he or she can be heavily involved, as observed with the detail designers in Company 1. Another example can be drawn from Company 4: although the attendance of all specialists in the meetings was the ideal case, organisational priorities forced technicians to delay their participation (late involvement) until they had a more active role and a "heavier" involvement.

There is a close relationship between the concept of involvement and the work-in-team concept. The earlier and heavier people were involved, the better the teams seemed to work. Hence, the concept of involvement may well be a category of the work-in-team concept.

5.2.3 A better explanation of concurrency and CE

From the previous analysis, an empirical concept of concurrency was induced, which hinged on three main concepts: convergence, parallel development, and work-in-team. These concepts are linked by a cause-effect relationship and include the conceptual categories of involvement, evaluating all aspects of the product life cycle, and release of information. These conceptual categories have, in turn, properties and dimensions. Figure 5-4 illustrates this conceptual structure in the form of a "mind mapping" tree.

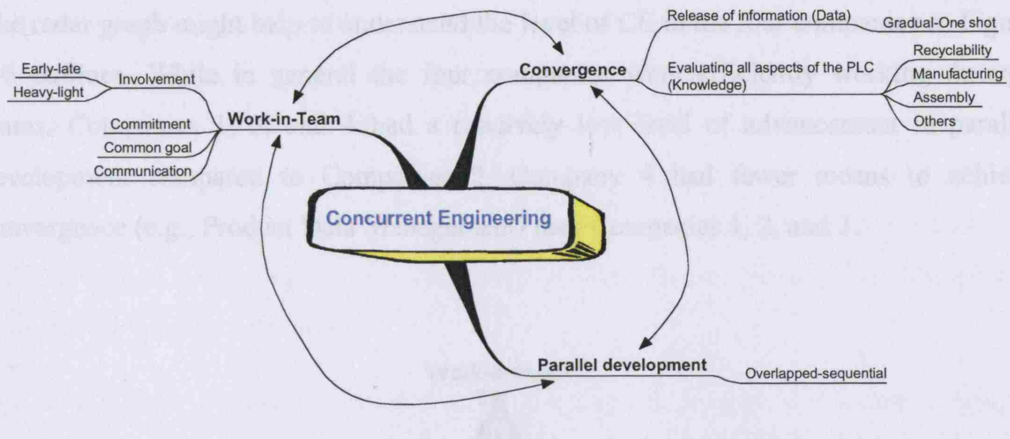

Figure 5-4. Conceptual structure of concurrency

Finally, by applying this empirically developed concept of concurrency, the following working definition of CE can be proposed:

> CE is an approach for designing products or services through the application of multidisciplinary teams working in parallel and converging on data and knowledge.

The next chapter discusses this definition at light of the extant literature.

The new concept of CE can be applied as an assessment tool using a radar graph as exemplified in Figure 5-5.

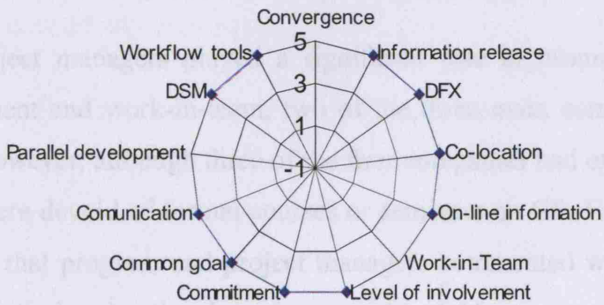

Figure 5-5. Radar graph including the main components of CE

The radar graph might help to understand the level of CE in the four companies as Figure 5-6 outlines. While in general the four companies were efficiently working through teams, Companies 1, 3, and 4 had a relatively low level of advancement in parallel development compared to Companies 2. Company 4 had fewer means to achieve convergence (e.g., Product Data Management) than Companies 1, 2, and 3.

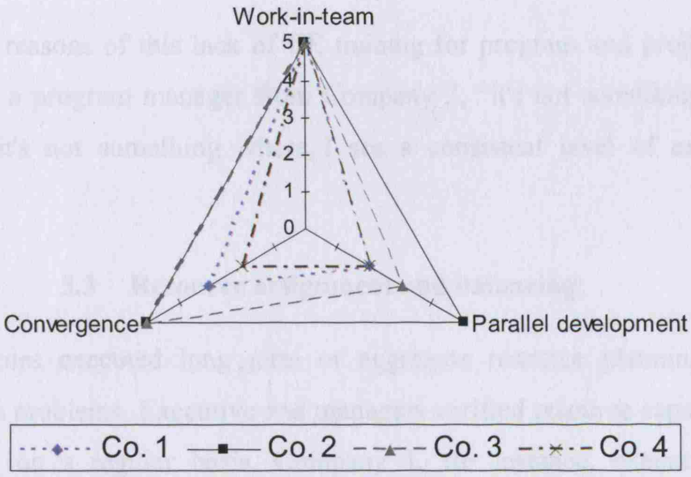

Figure 5-6. Gross comparison of meta-concurrent practices between the four companies through the radar graph

5.2.4 The lack of CE training for program and project managers

Program and project managers played a significant role in promoting (or inhibiting) parallel development and work-in-team, two of the three main components of the new concept of CE. However, although three of the four companies had extensive PM training programs, they were devoid of formal courses or seminars on CE. Furthermore, the field research revealed that program and project managers commented what they "had heard about" CE, not precisely what they have been taught of. Moreover, one program manager from Company 2 happened to ignore his role in applying CE by expressing the opinion that CE was being applied by the technical people. As explained earlier, the more significant comments on how CE works came from specialists and their heads.

This lack of formal training might have been the cause of a limited understanding of this approach and its implication in the way program and project managers dealt with their undertakings. It was evident, for instance, that some project managers believed that CE was primarily an approach to develop products in parallel and therefore a risky strategy. Other program and project managers had captured the essence of this approach however, and they were taking advantage of its main benefits (better quality, less rework and consequently shorter lead-times).

One of the likely reasons of this lack of CE training for program and project managers was expressed by a program manager from Company 3, "it's not something that people run courses on, it's not something where I see a consistent level of expectation or understanding".

5.3 Resource assignment and balancing

The four companies executed long term or aggregate resource planning to prevent resource constrain problems. Executive and managers verified resource capability against product portfolio on a regular basis. Company 1, for instance, executed aggregate resource planning every year, to estimate whether the existing capability would be enough to cope with the stream of projects considered in the portfolio strategy.

As shown in Table 5-5, the main problems for the companies did not seem to be the aggregate estimation of resources but: a) an inefficient assignment, levelling and control of resources on a project by project basis; b) scarce resources, and; c) a lack of an appropriate distributed server-type tool.

Table 5-5. Main problems relating resource management

Company 1
The management of resources during the first phase of the development ("selection") was not as efficient as in the second phase ("delivery") because managers required flexibility to cope with the ever-changing customer needs. During the "delivery" phase, the process of assigning and balancing resources among the different groups was relatively slow because of the absence of a distributed server-type tool.
Companies 2 and 3
Working through collocated teams made difficult to provide each team with the corresponding specialists for scarcity reasons. The geographical dispersion of facilities complicated the integration of teams.
Company 3
Solving resource conflicts was to some extent bureaucratic since the lack of a distributed server-type tool forced program mangers to wait until resource "councils" took place to negotiate resources.
Company 4
Team members could not participate in project meetings because of functional priorities.

Table 5-6 lists the most common PM-software tools used in the four companies. Company 1 was introducing Oracle Project Accounting™ to track peoples' time, Company 2 was using the PM module of SAP-PS™. Company 3 reported the use of an internally developed spreadsheet-type tool and, Company 4 estimated and balanced resources based on managers' experience.

Table 5-6. PM tools utilised in the four companies

Com pany	Tool(s) employed
1	MS Project™, Planview™, Oracle Project Accounting™ (It was being introduced)
2	SAP-PS™, MS Project™, Project Inceptor™
3	Spreadsheet type tool, internally made, MS Project™
4	MS Project™

Interestingly, although the four companies had PM tools (see Table 5-6), the most common being MS Project™, only managers from Company 2 reported to be performing resource assignment and balance supported by one of these tools, namely the SAP-PS™ system. The SAP-PS™ allowed managers to assign and balance resources across programs and projects. Likewise, managers could access real time information about resource capability. Before using SAP-PS™, Company 2 had two systems in place which were not totally compatible. An Engineering Director commented the main problem as follows:

> Prior to SAP-PS™ we had 2 systems that weren't integrated, we had a booking system where in effect you had a log of the program number and you allocated hours to resource groups who then booked. The program was separated from MS Project™ so you didn't have one system that you had the program and the booking. By introducing SAP that has gone company-wide.

The use of SAP-PS™ was not free of problems though. Firstly, the tool was useful at executive level, not at the level of work packages or during the day-to-day activities of the project. As commented in Ch. 4.2.4, there were cultural problems because people were not used to reporting their time in the system. Furthermore, the tool utilised earned value indices to monitor programs and some managers disliked this method as they were accustomed to monitor programs through Gantt charts and S curves.

5.4 Two perspectives of PM and the relationship with product development

Program and project managers were questioned about their activities and responsibilities, along with the differences between the two roles. Their answers are summarized in Table 5-7. Project managers were skilled at co-ordinating teams, planning, monitoring and controlling projects. They were responsible for the accomplishment of the project goals as required by the program. Some project managers dealt with several projects at the same time within a program but did it on a project-by-project basis. In Companies 2 and 3 team leaders and work package performed as project managers, that is, enacting the Pm execution perspective. In Company 4, the responsibilities and activities of the program manager did not differ substantially from the project manager either.

Program managers led endeavours or undertakings, called programs, which, depending on their size, were broken down into different, manageable sub-units. These sub-units were called projects or work packages. Then, project managers, team leaders, or work package managers (the name varied from company to company) managed these sub-units[5].

[5] Henceforth, only the role of the project manager will be considered because the role of team leaders and work package managers was essentially the same, i.e., leading manageable parts of the program.

Exceptionally, in Company 4 these sub-units were also managed by program managers since, as has been reported, the role of the project manager did not exist there. Program managers were skilled in managing multiple projects as they developed several products within their programs.

Table 5-7. Common characteristics of program and project managers in the four companies.

Program managers:	Project managers:
-were responsible for the projects within their programs; -liaised between project managers or specialists and top-level management; -co-ordinated project managers; -negotiated resources with functional areas; -set project priorities within the program. -were the company's representatives face to customers	-managed one or more projects within the program; -co-ordinated the specialists*: -were hired by and reported to program managers**; -planned, executed, and reported on a project by project basis.

* In Company 1 they also co-ordinated project managers from "Technology-domain" division, who in turn co-ordinated the specialists.

** Except in Company 4 where the role of project manager did not exist

Despite the similarities, program managers in the four companies had different responsibilities, roles and levels of authority. Table 5-8 shows the main differences and the particularities are discussed next.

The data shows that the role of program managers in Companies 2 and 3 were to some extent "stronger" than in Companies 1 and 4. They were responsible for technology transfer among the products of their programs and, depending on the contract type, they could lead the production and in-service stages. They monitored product performance in customers' facilities which enabled them to generate ideas for new products or modifications of existing ones[6]. The following product description of a program manager reflects this broader purview:

[6] In Company 1 and 4, the product managers and the business development managers respectively (not the program managers) were responsible for monitoring products in the market.

> We have engines of two sizes, which are relatively young products, they're both in production, but they also have product development opportunities. And the majority of the opportunity is on the big engine. So, we spend most of our time thinking about the product development of this big engine to ensure we maintain and enhance our competitive position. So in that sense, where we want to move the big engine is very much driven by what we think the needs of the market are.

Table 5-8. Comparative responsibilities, roles and levels of authority of program managers in the four companies

Program managers in:
Company 1 - shared product responsibility with heads of product managers during product development; - handed over the project after product launch; - had no responsibility for monitoring product performance in the market; - reported to a functional head (group chief designer)
Company 2 and 3 - owned customer contracts; - had "cradle-to-grave" responsibility, that is, co-ordinated production and in-service stages*; - had co-responsibility for monitoring product performance in the customers' facilities - reported to a head of programs (program director)
Company 4 - handed over the project after product stabilisation - had no responsibility for monitoring product performance in the market - reported to a functional head (Quality assurance manager) - performed as project managers

* In some programs

They were also responsible for the accomplishment of the business goals throughout their programs. As stated by a program manager:

> My new role will be responsible for projects to develop this set of products within this region. So there's maybe half a dozen project managers that will be reporting to me, so I'll be responsible for that small area of the business.

The implementation of business orientated PM approaches in Companies 2 and 3 happened to indicate that Pm evolved towards a PM broader perspective. In both cases, practitioners mentioned that they had PM practices that were less integrated and functioned merely as a "coordinative role". Latter, PM became a company wide framework in Company 2 in the form of the IPM (Integrated Program Management) or a Program Management business-orientated approach in Company 3. When the new business-orientated approaches were launched in the two companies program managers received executive training and even an MSc on the subject. They also started to focus on long-term strategic program goals (business related) rather than short term projects goals.

The functions and training described above suggest that program managers in these companies enacted to some extent the PM broader perspective. Comparatively speaking, the responsibilities and authority of the program managers were similar to those of the "heavy-weight" product manager or "susha" (Clark and Fujimoto, 1991). However, neither the project/product portfolio nor the business case were managed by program managers. In Company 1, the former was managed by the head of Product Management, that is, by a commercial division of the company. In Company 4 it was managed by the business development managers who also had a commercial orientation. Unfortunately, this topic was not investigated in Companies 2 and 3 mainly because it did not emerge in the data collection. On the other hand, the business case was developed in all four cases by commercially orientated departments.

The application of Program Management in Company 4 was so limited in scope that no significant differences with the PM execution perspective were found (see Table 5-8 and the Case Study description). In this respect, a program manager pointed out that their projects differed from those one-of-a-kind "discrete capital projects" where considerable investments were required. He then added that:

> Basically the way of working within the motor industry that I work with, and that is that each program is very similar to the previous one, so it's more similar than a nuclear power station or to a new dam. And the techniques that we use are to, basically to add structure, so that, and as a checklist to remember exactly what we have to do.

Then the program manager was asked why they were not called project managers and his answer revealed that the term "program" was a sector-related term:

> Program is a more accurate description of what we do. A program is a development program, and I suppose semantically, if you say a development project, in the motor industry, you would mean something where you were running an experiment and you're going to try something and see what happens. But the program really has come to mean taking products from concept into production, in a structured way.

In Company 1, program managers managed programs or "propositions" based on customer needs rather than based in specifications, as in Companies 2 to 4. For instance, a proposition was launched to address the following customer need: "providing colour rich devices". It consisted of developing, amongst others, new colours, new sub-data services, and different types of messaging. Some of these new features were created during the program. Thus, propositions were like spin-offs and program managers had to be able to transfer new technologies into their programs.

5.5 How the relationship between CE, NPD, and PM was understood in terms of purpose, sub-components and precursors

Managers who had participated in the implementation of CE, NPD, or PM practices were asked two specific questions: a) how do you understand the relationship between these approaches? b) In which order have they been implemented or in which order would you implement them? These questions were intended to discover whether one approach was a sub-component or a predecessor of the other or whether they were different in purpose. Table 5-9 summarises the experts' opinion about the first question.

Table 5-9. Different opinions about the relationship between CE, NPD, and PM*

Company 1
The NPD is a business process to select and develop the *right* products to market. It is considered as a filter process to ensure that investments are addressed only to the most promising products. PM (represented by PRINCE 2) is a methodology to deliver the *right* products *right*.
Company 2
- PgM defines the *what*, NPI (the technical process to develop products) defines the *how*, and CE is embedded into the NPI. In other words, the *how* should be done concurrently. - The thing about concurrent engineering is that it's saying that you're going to make sure that the right people are there at the right time to make the right decisions. The fact is that IPT (Integrated Program Teams) says the same thing; program management says the same things. There isn't actually any difference between.
Company 3
- From my perspective, the two disciplines (PM and CE) grew up at different times and for different reasons. However, I think any endeavour aimed at managing an activity of outcome is bound to coincide in some way with an approach with similar or overlapping objectives. I think this is where you uncover contradictions when you try to synthesise the thinking. - They were all aimed at solving different problems in industry ... I think this NPM process is quite a good way of visualising it. ... So the theoretical boys are quite right, they are looking at their own world, but the practical world, that either we've defaulted into unknowingly, or have engineered ourselves into, has actually taken each one of those and pulled it under a kind of single process.
Company 4
Here we work within very formalised Advanced Product Quality Planning procedures based originally on the requirements of QS9000. We are now working to ISO TS16949 standards against which we are audited twice a year. The three approaches that you describe are all integrated into our procedures - but work to a greater or lesser level of effectiveness.

*Some comments refer two approaches only

The comments made by practitioners describing directly or indirectly (through their approaches, e.g., NPI, IPM and so on) the purpose or the aims of CE, NPD, and PM were gathered and are presented in Table 5-10.

Table 5-10. Comments directly or indirectly relating what CE, NPD, or PM are aimed to (purpose)

Company 1	NPD defines the what; it is to deliver the right product; it adds visibility; it is and end-to-end business process focused on commercial aspects. PM (PRINCE 2) defines the how; it is to deliver the product right; it is a way to develop the NPD process.
Company 2	NPI is to meet specific customer requirements. IPM is to manage every program; DP is to appropriate project management control of the NPI. CE defines the how (concurrently); it is to improve engineering processes.
Company 3	NPM is to manage the introduction of new products and major modifications; it is a way of managing projects throughout the business; it is to add structure; it is to make sure that the business was investing correctly; it is a good way of visualising. NPI is the technical road; it is how the projects should be managed. CE is how to do it better and better. PM is a tool that can help to deliver CE.
Company 4	DDI is to put structure into our activities, to put together a thorough process

Table 5-11 shows the order in which the CE, NPD, and PM related approaches were implemented in the four companies. This information was gathered through interviews as documents relating the chronological order of implementation were not available.

Table 5-12 shows the answers from some experts that were specifically questioned about a recommended order of implementation because they had been involved in the implementation of more than one approach. Both the chronological and the recommended order of implementation agree to some extent. However, the detailed analysis and discussion of the arguments and comments expressed by practitioners regarding purpose and precedence will be carried out in the next chapter in an effort to synthesis the thinking and clarify the differences and similarities.

Table 5-11. The likely chronological sequence of implementation

Company 1	PM was first in place when the organisation was based on business units. NPD was later implemented when the business was reorganised in divisions. PRINCE 2 was the last approach to be implemented within the EDEN program to manage every program in the company
Company 2	Program management was first in place as well as technical procedures. CE started in the 1980s in order to improve engineering practices The NPI and IPM and DP happened to be the last approaches to be implemented as a result of the new business vision of the company.
Company 3	PM was being applied but it was considered as a coordinating function. CE was developed in the 1980s in order to do the engineering better. NMP was implemented approximately in year 2000 to have an end-to-end business process. NPI was the last framework to be implemented attempting to integrate the different practices developed throughout the business.
Company 4	Program management and cross-functional teams were in place for about ten years. DDI-APQP was implemented around five years ago to integrate the teamwork, program management, and technical processes as well.

Table 5-12. Experts' opinion about the implementation order between CE, NPD, and PM

Company 1
It depends where you start from. We had a number of project management methodologies, we had a variable quality of project managers, we had no process, and therefore no decision, you need to put the NPD process in. If we started a new company, and no process and no project management skills, then some of the basic skills of project management would probably have had to come first, then define the process. But really the two go hand-in-hand and one doesn't necessarily take precedence over the other.
Company 2
There has always been program management, because you can't do anything without program management, but the program management we have today, and the way we do program management is completely different to the way we did it 20 years ago. What we haven't had before is integrated program management and the IT system to support it and the IPM philosophy, which is only five years old. Prior to that was concurrent engineering, which I said we started looking at about mid-80s. First in place was processes - what do we need to do, how do we do it. Then we've taken the same basic processes, altered how things happen, when they happen to provide concurrent engineering, and then we've taken that evolving situation and wrapped around it a way of more effective program management and resource management.
Company 3
What came first was the individual engineering processes that each business had in the past. Then project management was established, with focus on training people in project management techniques, and this is maybe going back 10 years. Then NPM was established to make sure that the business was investing correctly and that we would have high-level control in our projects. Then we looked at things and said some of our projects are now multi-site, multinational, and we need to make everybody best practice, so then this NPI process was standardised. Concurrent engineering has progressively developed in the last, I would say, 15 years. We've learned how to do it better and better over that period. So multifunctional collocated project teams were really established about 5 years ago.
Company 4
(Not any expert had been involved in the implementation of more than one approach)

5.6 A process model to understand the relationship between CE, NPD, and PM

The application of different yet aligned processes to develop new products was a common pattern observed in the four companies. These processes were named differently in each company but, given their characteristics, were related to CE, NPD, PM, or combinations thereof. The processes started and finished at different points along the product life cycle, though they were linked through gateways, milestones or review points.

5.6.1 Aligning-process schemas

Table 5-13 portrays a brief comparison of the main processes to develop new products applied in the four companies. The four companies had business-orientated "umbrella" processes around which other surrogated processes or procedures run. In Companies 1, 2, and 3 different PM-orientated processes or frameworks were used for managing the main umbrella processes. In Company 3 several program and project managers believed that the umbrella processes were PM-orientated (the broader PM perspective) but this was questioned by functional heads and some managers who believed that PM-orientated processes were surrogated to these business processes (the Pm execution perspective). In Company 4 the DDI process was at the same time the business-orientated umbrella process and the Pm procedure guide for program managers.

Table 5-13. Processes to develop new products as applied in the four companies

Company	Umbrella processes	PM orientated processes or "frameworks" for managing the umbrella processes
1	New Product Development (NPD). Six stages and milestones.	PRINCE 2. Six stages.
2	New Product Introduction (NPI). Six stages and ten reviews.	Integrated Program Management or Directing Programs. Three stages and five technical reviews
3	New Product Management (NPM). Five phases and seven gateways.	New Product Management or New Product Introduction*
4	Design Development and Introduction (DDI). Eight stages and eight checklist reviews.	Design Development and Introduction

*Opinions differed between program managers and functional heads and specialists

These and other processes (like procurement, production readiness and in-service readiness processes) were *aligned* along the project life cycle through gateways or milestones. A graphical representation of this *alignment* is shown schematically in Figure 5-7, which will be called aligning-process schema (APS).

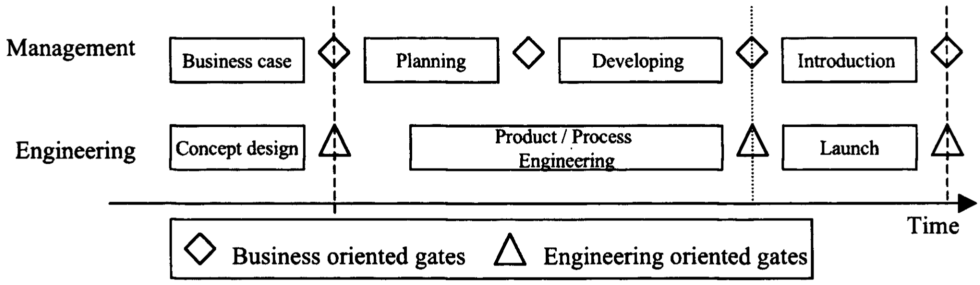

Figure 5-7. An example of processes alignment or an aligning-process schema.

Check-lists were generated by each of the different functional groups to verify the accomplishment of all the important decision variables, regardless of the nature of the process (business or PM-orientated). Every check-list was reviewed during meetings taking place at pre-defined intervals. Table 5-14 shows some of the typical decision variables included in these check-lists.

Table 5-14. Main decision variables associated with different functions.

Business or commercial*	Project	Engineering
Level of investments Fit between the product being developed and portfolio strategy Forecasted profits Product cost Market acceptance.	Project lead-time Project cost Project risks	Product performance (scope and quality) Customer requirements compliance Product risks

* The term "commercial" was more common in Company 1, whereas the term "business" was more common in Companies 2 to 4.

Some processes were internally developed, such as the NPI and the NPM in Companies 2 and 3. Other processes were adapted from known NPD models, such as the NPD process in Company 1 or the DDI in Company 4 (adapted from the APQP) or from PM frameworks such as PRINCE 2 in Company 1.

Different practices, tools, and techniques underpinned every process. Managers from Companies 2 and 3 emphasised that CE practices were embedded in the engineering processes. The corresponding lists of techniques and practices, classified by the nature of the processes, are presented in the appendices of chapter 4.

5.6.2 Asynchronous processes and ownership (business managers, program managers, chief engineers)

The processes to develop new products started and ended at the different points in time along the development. An example of this kind of *process asynchrony* was the aligning-process schema developed by managers in Company 3 (see Chapter 4) which showed that "production readiness" and "In-Service readiness" were two processes that started after "system" and "product" development processes.

Both the start and end point of the processes that involved CE, NPD, and PM were investigated in the four companies by asking people when their participation began and ended. Table 5-15 presents a summary of the different answers arranged by the nature of the processes, i.e., NPD, PgM, PM-execution and CE related (see the case studies for a detailed explanation).

From this empirical information, illustrative schemas showing the starting and ending point of the different processes and the process owners were generated (Figure 5-8) where the main processes employed in each company, and the corresponding stages are included in the schema (in gray lines) as a reference point.

In general, business processes showed a longer life cycle than Program Management processes and these in turn exhibited a longer life cycle than Engineering (and project management) processes. In Company 1, product managers owned the commercial process whereas in Companies 2 to 4 the business processes were owned by business managers first and then by program managers. Engineering processes had the shortest life cycle, were owned by specialists (Chief designers of Chief engineers) and included the CE practices.

Table 5-15. Participation start and end of different roles in the four companies

People interviewed	**From company**	**When did their participation...**	
		Start?	**Finish?**
NPD or commercially related			
Product managers	1	When somebody came up with a new idea.	After developing the business case and project authorisation. However, they were involved again to monitor product performance
* Business managers	2, 3, 4	When business opportunities were identified or an RFQ was raised	After developing the business case and the contract was awarded or rejected
PM related			
**Program managers	1	At the middle of stage one (Idea Generation) to help in planning the following stage	After a post project review meeting, approximately three months after product launch
	2 and 3	At the beginning of stage one (Concept Definition) to co-ordinate the teams participating in the quotation process.	Depending on the extension of the contract. It could be at product launch to production, at the end of production, or at the end of a contracted service
	4	At the middle of stage one (Receipt and Process RFQ) to co-ordinate the quotation process	After a period of product stabilisation (Stage 7)
CE or engineering related			
Group chief designer and specialists	1	At the "idea generation" stage to conceptualise technical alternatives for the new ideas	At the end of stage six (Product Launch)
Chief engineer and specialists	2 and 3	At the beginning of the first stage (Concept Definition) to convert product requirements into product attributes	At the end of the Product Realisation or Production Ramp-up stages respectively
Product development manager and specialists	4	At the middle of stage one (Idea Generation) to make gross estimations of cost and product parameters	At the end of stage eight (Product Stabilisation)

* These people could not be interviewed, the information was gathered indirectly from other informants or documents.

* * Project managers entered and exited from programs depending on the type of products to be developed, the nature of the stage of the program, or the program's capability requirements and constraints.

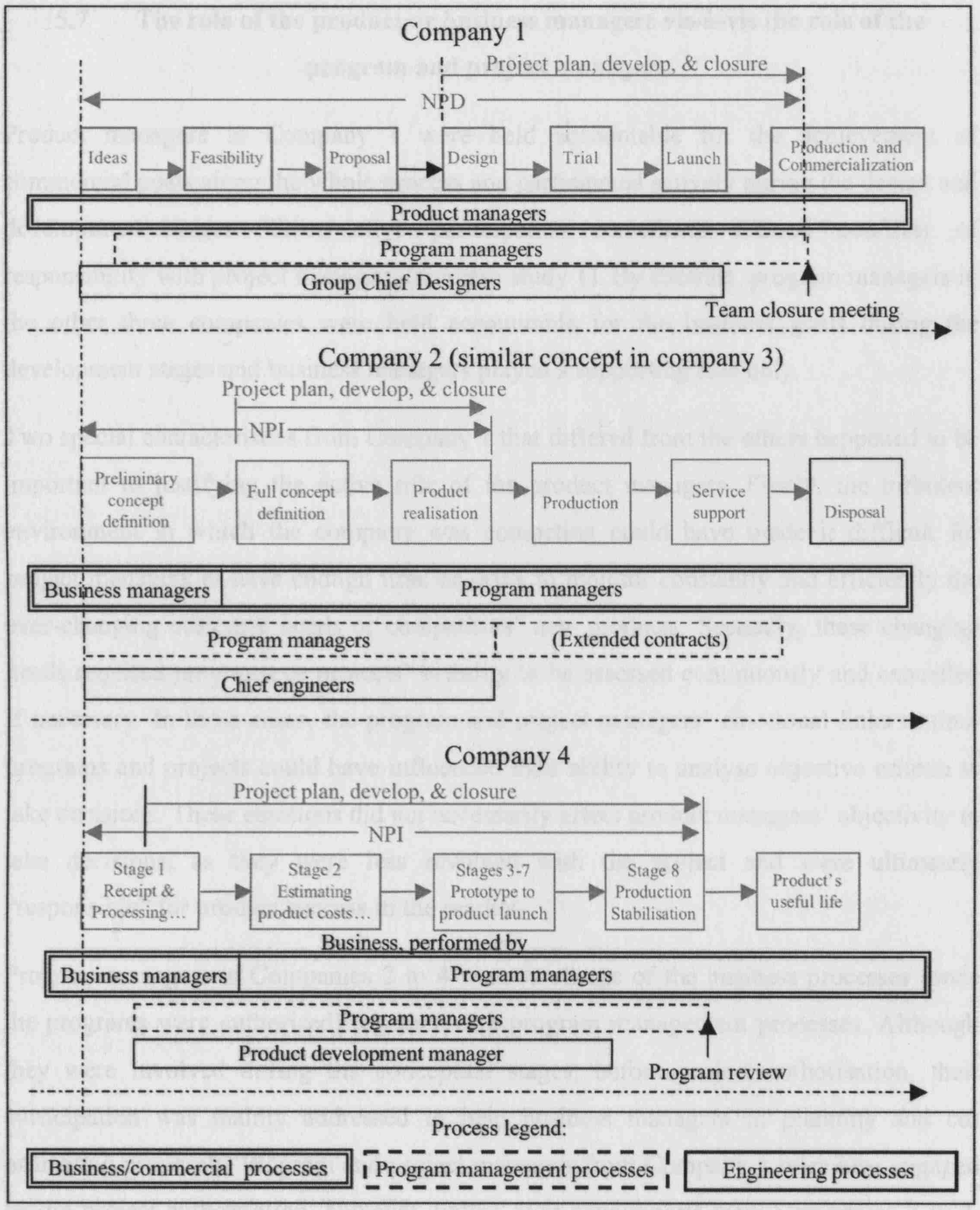

Figure 5-8. Start and ending point of three different processes and process owners.

5.7 The role of the product or business managers vis-à-vis the role of the program and project managers.

Product managers in Company 1 were held accountable for the achievement of commercial goals along the whole process and participated actively during the design and development stages. This active participation sometimes created conflicts of responsibility with project managers (see case study 1). By contrast, program managers in the other three companies were held accountable for the business goals during the development stages and business managers played a supporting role only.

Two special characteristics from Company 1 that differed from the others happened to be important to justifying the active role of the product managers. Firstly, the turbulent environment in which the company was competing could have made it difficult for project managers to have enough time or skills to monitor constantly and efficiently the ever-changing customer needs or competitors' new products. Secondly, these changing needs required programs or projects' viability to be assessed continuously and cancelled if necessary. In these cases, the program and project managers' emotional links to their programs and projects could have influenced their ability to analyse objective criteria to take decisions. These emotions did not necessarily affect product managers' objectivity to take decisions, as they were less involved with the project and were ultimately "responsible" for product success in the market.

Program managers in Companies 2 to 4 were in charge of the business processes (once the programs were authorised) together with program management processes. Although they were involved during the conceptual stages, before project authorisation, their participation was mainly addressed to help business managers in planning and co-ordinating proposals. Program and project managers from Company 1 were also engaged before project authorisation, however, unlike their counterparts from Companies 2 to 4, they were not in charge of the commercial or business process.

At the other end of the development, program managers from Companies 2 and 3 extended their participation to production and in-service stages in some contracts, that is, beyond product launch to production. This extended scope of PgM is even longer than the life cycle appointed by the APM framework (PMBOK-APM, 2000) since the latter does not include the in-service stage. Likewise, the extended participation of program managers and their teams facilitated the conditions for a simultaneous development of the product and the service. This favourable condition represents an insight for those companies that want to develop products and services simultaneously. According to Levene and Goffin (1998), this is an area of research that has not been fully exploited.

The process asynchrony depicted in Figure 5-8 shows that program managers did not prepare the business case: this was done by product and business managers. Program managers, however, were responsible for its accomplishment. For instance, in Company 1, program and project managers made crucial decisions regarding time and costs that in turn affected the financial projections originally stated in the business case. In Companies 2 to 4 the business case was passed directly on to program managers after project authorisation. The following explanation from a project manager from Company 3 indicates that the plausible reasons might lie in the need for a balanced division of work or perhaps on cognitive grounds:

a) Lack of resources: companies could not engage a project manager for every emerging idea since they had a limited number of project managers.

b) Long negotiation stage: in some cases, the negotiations to win a contract took considerable time, much of which was "on hold" time, waiting for customer answers or feedback.

c) Highly technical inception stage: the activities to conceive an idea could be so technologically challenging and unstructured that the assignment of a project management team at this stage would not add real value (particularly in companies such as Company 1).

In summary, the comparison between program or project managers and product or business managers in the four companies (drawn also from Ch. 4), is shown in Table 5-16.

Table 5-16. Comparison between program or project managers and product or business managers

	Product/Business managers	Program/Project Managers
Main role		
Company 1	Managing products in the market and ideas for new products, preparing the business case	Developing or "delivering" new products projects
Companies 2 and 3	Attracting new customers and lobbying actual ones, preparing the business case	Developing contracts and monitoring product performance in the market (extended service)
Company 4	Attracting new customers, proposing new ideas, preparing the business case	Develop new product projects
Responsibility during the pre-contract or before project authorisations		
Companies 1 and 4	Main responsible	Assistance in developing plans and coordinating specialists for preparing the business case or quotation
Companies 2 and 3	Main responsible	Consulted and involved in quotation preparation (2 and 3)
Responsibility during the development		
Company 1	Active participation	Main responsibility
Companies 2 and 3	Consulted	Main responsibility
Company 4	Consulted	Main responsibility
Responsibility for product improvements after product launch		
Company 1 and 4	Main responsibility	None
Company 2 and 3	Co-responsibility	Co-responsibility
Organisational level of the function's main representative		
Company 1 and 4	Higher	Lower
Company 2 and 3	Similar	Similar

5.8 Summary

The empirical evidence gathered from the four case studies was used to induce a different concept of concurrency and a corresponding definition of CE where three fundamentals emerged, namely, work-in-team, convergence, and parallel development.

The evidence gathered in the field showed that CE in general was not associated with a risk of rework. However, three companies considered that parallel development was indeed a risky strategy whereas in one company (Company 2) managers considered that the sequential approach was riskier because of the over-the-wall syndrome. Different CE-type tools and techniques were applied in this company to prevent the risk of rework of the parallel approach.

The case study descriptions and the cross-case analysis confirmed the lack of formal CE training for program and project managers. The evidence indicated that, while the role of program and project managers in the application of CE is significant, there were not CE courses or seminars for program and project managers addressing this important approach.

The relationship between CE, NPD, and PM was understood differently by managers, and the order of implementation happened to be as follows: first in place was the PM execution perspective which evolved towards a business NPD or PM perspective. CE was implemented before the adoption of PM or NPD business approaches.

The cross-case analysis revealed that both the PM broader perspective, in the form of PgM, and the Pm execution perspective were being applied to develop new products in the four cases. The former was enacted by the activities and responsibilities of program managers, and the latter by project managers, team leaders, and work package managers. However, Program Management (PgM) was conceptualised differently in each case (as it happens in the literature) while the Pm execution perspective was more uniformly understood. Evidence confirmed that elements of the MP (the Management of Projects) perspective were also being applied despite the fact that the approach was practically unknown by practitioners. This finding might suggest that the MP perspective stills lacks of positioning in the manufacturing or telecommunication industry.

Another common pattern observed in the four companies was the application of processes to develop new products. Each process entailed a set of specific decision variables like business, commercial, project, technical, production readiness and so on. They may be adapted from an NPD, PM, CE or any other known or homemade approach. The processes were linked through aligning schemas which were mechanisms that showed where the processes coincided along the product life cycle. The points of coincidence were commonly called milestones, gateways, and so on. The processes were closely intertwined, however they did not start and end at the same time, that is, they were asynchronous. By asking practitioners when their work started and finished, process patterns were developed showing asynchrony between them. The data also suggest that business processes tend to embrace program management and engineering processes.

The relationship between the product manager or business development managers and project or project managers was described. In general, product and business managers in Companies 1 and 4 had business responsibilities while programs managers were responsible for the development of the product. Product managers and business managers were responsible for monitoring products in the market and for introducing new ideas. In

Companies 2 and 3 business managers handed over the business responsibility to program mangers after awarding a contract. Program managers also had responsibility for the development of the product and in some contracts for the extended service. Both business and program managers were responsible for monitoring products in the market and for introducing innovations.

Finally, the cross-case pattern showed that there was a need for simpler, yet accurate tools to assign and balance resources in the four companies.

Chapter 6 Discussion, implications and limitations

The research questions are explained and the theoretical issues discussed based on the case studies and the cross-case analysis. The findings, conjectures, and concepts are discussed in light of the extant literature to refine the explanative framework and to highlight the implications. Finally, the limitations of the study are discussed.

6.1 CE, an all-encompassing term

1. What is nowadays the meaning of Concurrent Engineering for practitioners?

As reported in Chapter 4 and 5 the term Concurrent Engineering was not recognised by most people in case studies 1 and 4. Moreover, managers in Company 1 affirmed that they were not applying CE despite the fact that the evidence confirmed that they were doing it (see C.S. 1). Practitioners in Companies 2 and 4 were familiar with the concept but they did not consider that techniques typically appearing in CE taxonomies like QFD and FMEA were necessarily part of CE. The companies had not launched initiatives, projects or programs under the name of CE (see table 5-2). Managers in two companies commented that CE lacked of a consistent level of understanding.

The evidence suggests first that CE might be lacking of recognition in certain types of companies. Second, it did not happen to represent many different things for practitioners as it is presented in many literary sources. CE was not an initiative or an approach *per se* but several approaches pursuing a more efficient way of engineering the products as in company 2 and 3.

The lack of recognition might be retarding the development of the subject as in companies 1 and 4 and therefore it is believed that more precise definitions are needed for managers to better understand the benefits and efforts required to implement CE. This concern was expressed by Cleetus and Reedy (1992) in the early 90s, when there was still a modest quantity of publications on the subject.

2. How can the meaning of concurrency or concurrent be explained in order to avoid confusions with terms like parallel, simultaneous or teamwork?

The analysis of the data suggests that concurrent or concurrency could be understood as a combination of parallel development, work-in-team and convergence (see Ch. 5.2). Parallel development refers to the simultaneous problem-solving approach described among others by Clark and Fujimoto (1992) where downstream activities start before upstream activities finish and this occurs through an intense information exchange to avoid rework (as it was observed in Company 2). Work-in-team involves multidisciplinary teams working together and committed to the achievement of a common goal. Convergence means that data and knowledge tends to one point of focus from which are shared and used by the different users.

Four types of convergence were observed in the companies and described in Chapter 5: meetings, co-location, public boards, and on-line. The means of convergence observed in practice suggest a more general framework for convergence, as illustrated in Table 6-1. The concept of "arenas" is included in the framework and refers to forums where developers concur to interactively solve problems in product development (Söderlund, 2002). Similarly, the *Zen-in* Design Room at Xerox is an example of both physical and virtual convergence, where everyone participating into a development project comes together or discusses any problem "over virtual, real-size, three dimensional graphic models in the earlier phases of the development process". (Umemoto et al, 2004: 94).

Table 6-1 Framework for convergence

	Synchronous	**Asynchronous**
Physical	Meetings and teams co-location, "arenas", "Zen-in design room".	Public boards, exhibitions, mock-ups
Virtual	Video conferencing, Telephone, chat.	E-mail, e-groups, Intranets, "Zen-in design room".

Another means of virtual and asynchronous convergence are the companies' intranets where designers can review engineering solutions developed worldwide by partner offices. The usefulness of these tools was recognised by Arup engineers when they discovered that the design group of the Millennium Bridge in London could have avoided the "wobbling problem" of the bridge, had they posted in the intranet an engineering solution already developed by the Arup's Japanese office (Dodgson et al, 2004).

The empirically induced concept of convergence (see Ch. 5.2) is thought to be a contribution to try to clarify the existent confusions between concurrency and parallel or simultaneous development. As stated above, convergence is a conceptual property of the new definition of concurrency which will be named *meta-concurrency* in order to differentiate it from others already appeared in the literature (not always clearly defined) and also because *meta* is a prefix that signifies [1]*beyond or transcending* and the connotation is precisely of a *more comprehensive* concept.

The empirical model of meta-concurrency (Figure 5-4) suggests that multidisciplinary teamwork on its own is not the same as concurrency, as was perceived by practitioners (see Ch. 4) and academics (see Ch. 2), but as one of its conceptual categories.

Loch and Terwiesch (1998) differentiated two types of concurrency:

> Time concurrency refers to activities that are performed in parallel by people of different groups. Information concurrency refers to the degree to which information is shared among the involved parties. (Loch and Terwiesch, 1998: 1033)

"Time concurrency" corresponds to parallel development in the new definition of meta-concurrency and "information concurrency" is equivalent to convergence. Hence, meta-concurrency is a concept that considers both conceptual properties proposed by Loch and Terwiesch's.

Maylor and Gossling (1998) asked practitioners how concurrency was defined but unlike this research the authors did not synthesize a definition. Nine key features emerged which were compared with the three main conceptual categories of meta-concurrency (Table 6-2). All the key features gathered by the authors are included in meta-concurrency with the exception of "Leadership required for the whole project", a characteristic that did not emerge in the research field.

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[1] The American Heritage® Dictionary of the English Language, Fourth Edition Copyright © 2000 by Houghton Mifflin Company, www.dictionary.com, accessed April 8th 2006.

Table 6-2. A comparison of concurrency's key features (Maylor and Gossling, 1998) and meta-concurrency main conceptual categories

Concurrency's key features (Maylor and Gossling, 1998: 70)	Meta-concurrency main conceptual categories
Manufacturing and engineering working together	Work-in-team
Multi-functional teamwork	Work-in-team
Collective team responsibility	Work-in-team
Replacing sequential activities with concurrent activities	Parallel development
Shifting planning activity to the front end of the project	Convergence (see section 5.2.2.5)
Leadership required for the whole project	Not included
Obtaining customer input	Convergence (se section 5.2.2.4)
Project staff dedicated for life of project	Work-in-team
Getting consensus decisions.	Work-in team

Similarly, authors have proposed CE main components (Koufteros et al, 2002) or "thrusts" (Pawar et al, 1999) (Table 6-3) which are considered within the three main elements of meta-concurrency.

Table 6-3. Comparison of CE main thrusts, components or elements.

Authors	CE thrusts or components	Comparison with meta-concurrency elements
Pawar et al, 1999: 215	Thrusts: parallelism of different but hitherto sequential activities, and early involvement of all enterprise functions	Parallelism is equivalent to simultaneous or parallel development. Early involvement is a property of convergence
Koufteros et al, 2002: 334	Components: cross-functional teams, concurrent work-flows, and early involvement	"Cross-functional teams" is equivalent to work-in-team. Concurrent workflows and early involvement is similar to convergence

3. How can CE be better explained?

By integrating the three main conceptual categories of meta-concurrency, the following working definition of CE or *meta*-CE (to distinguish it from other CE concepts) is proposed:

> Meta-concurrent engineering is an enhanced approach to engineer products through the application of multidisciplinary teams working in parallel and converging on data and knowledge

In order to evaluate whether simplicity and precision was achieved, the definition was compared with two of the most recognised CE definitions: Winner et al's (1988) and Cleetus' (1992). Pfeffer's (1982) suggests that good theory is parsimonious, testable, and logically coherent and, although definitions are not theory, conceptual definitions are the building blocks of the theory (Glaser and Strauss, 1967; Eisenhardt, 1989; Handfield and Melnyk, 1998; Amundson, 1998). Therefore, these criteria (parsimony, testability and coherence) seemed appropriate points from which to make the comparison (Table 6-4).

Table 6-4. A comparison of two CE definitions with the concept of Meta-CE.

	Winner et al, 1988	Cleetus, 1992	Meta-CE
What is Concurrent Engineering?	CE is systematic approach to the integrated, concurrent design of products and their relate processes, including manufacture and support. This approach is intended to cause the developers, form the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements.	CE is a systematic approach to integrated product development, that emphasizes response to customer expectations and embodies team values of cooperation, trust, and sharing in such a manner that decision making proceeds with large intervals of parallel working by all life cycle perspectives, synchronized by comparatively brief exchanges to produce consensus.	Meta-CE is an enhanced approach to engineer products through the application of multidisciplinary teams working in parallel and converging on data and knowledge.
Parsimony (simplicity)?	Less	Less	More
Testable?	Yes	Yes	Yes
Logical coherence?	Less	More	More

As can be appreciated, the concept of CE developed in this thesis is thought to be more parsimonious because it is based on less conceptual properties which, according to the field study, represent the essence of CE: multidisciplinary teams, work in parallel, and convergence (covering early release of information and the use of upstream data on design activities).

The new definition can be tested since every one of their components has conceptual categories and dimensions (see Chapter 5). For instance, it can be empirically tested to what extent a company develops activities in parallel (see for instance Krishnan, Epinger and Whitney, 1997). Undoubtedly, Winner et al's and Cleetus' definitions are also testable since they have been utilised in many different studies.

Finally, the concept is logically coherent since the empirical characteristics of meta-CE were differentiated and integrated. Winner et al's definition uses a circular reference, that is, it uses the word concurrent to define concurrent engineering, which is not logically coherent.

"It is unlikely that we can escape the trade-off among simplicity, accuracy and generality in creating process theories" [Pentland, 1999:721]. In particular, accuracy tends to conflict with both simplicity and generality (Langley, 1999). Hence, the new concept seems to be less precise as it does not include conceptual properties included in Winner et al's and Cleetus' like quality and cost, or customer needs and suppliers as in other definitions (Willaert etal, 1998). Therefore As for generality, the new definition might lay at the same level as the other two since they have similar application scope, i.e., design or engineering.

6.2 CE tends to reduce rework

4. What is the practitioners' experience and perception about sequential and parallel development and the risk of rework?

The evidence shows that practitioners from Companies 1, 3, and 4 considered that developing activities in parallel was prone to rework while practitioners from Company 2 commented that this practice was less risky than the serial approach because this last produced designs that could not be later manufactured. Practitioners from three companies (2, 3, and 4) considered that the practice of approaching product development through integrated program and collocated teams or simultaneous development teams (a basic CE ingredient) tends to reduce the risk of rework.

Company 2 showed evidence of systematic planning of activities in parallel. The planning and execution of activities in parallel required high levels of communication and to face this stringent condition teams were co-located and workflow tools were used. The approach was similar to the simultaneous problem-solving approach described by Clark and Fujimoto (1992) where an intense two-way information exchange was produced in order to tackle the problems between design and manufacturing early on. Then, the evidence suggests that the parallel approach can be apparently less risky than the serial one providing that the necessary means to increase the levels of two-way communication (or convergence on information) between upstream and downstream functions are in place. As observed in the other companies, the application of multidisciplinary teams helps in this effort but it is apparently not enough.

These results help to explain why most CE authors do not consider CE risky (e.g. Hartley, 1992; Prasad, 1996; Al Ashaab, 1999; Maylor and Gossling, 1998; Swink et al, 2006), because CE is more than simply developing activities in parallel. On the other hand, studies showing the negative or null effects of overlapping or fast tracking (e.g. Morris, 1997; Eisenhardt and Tabrizzi, 1995; Williams et al, 1995; and Ibbs et al, 1998) might have studied projects not approached through CE. Overlapping without work-in-team and convergence on information is thought to be equivalent to the "old concurrency" or "fast tracking" approach identified by Morris (1997) as an approach that caused many project failures. When fast tracking has to be applied, for instance when the project is behind schedule, risk management techniques should be considered, as mentioned by practitioners in Companies 1, 3, and 4.

Bhuiyan (2004) found that overlapping is recommended in projects with low levels of uncertainty and Terwiesch and Loch (1999) found that overlapping was advantageous if project uncertainty was resolved early. Although project uncertainty was not particularly investigated in this research, the results do not happen to confirm those contingent propositions to manage overlapping. First, Company 2 was overlapping activities despite the fact that they were designing and developing highly complex products where the levels of project uncertainty are supposed to be high particularly at the outset. Second, evidence showing that the level of uncertainty was resolved early on was not found and practitioners did not mention it as a condition for overlapping.

Practitioners in the four companies perceived more benefits on quality than in lead-time reduction after introducing CE practices. Their CE approaches effectively reduced rework but not always lead-time. As stated before, Companies 1, 3 and 4 developed relatively few systematic actions to develop activities simultaneously and nonetheless they reported lead-time reductions which were achieved through less rework.

Unlike the literature on CE, cost reductions or higher return on investment were not mentioned in the case studies amongst the main benefits. Perhaps it was implicit for interviewees that less rework and better product quality implied cost reductions, both in the short and long-term. Perhaps managers interviewed did not have enough involvement in project costs or investments. Lawson and Karindakar (1992: 4) found that "67% of interviewees did not know what the return in investment was for their organization's CE program".

6.3 Different criteria for sequencing activities and the lack of DSMs usage by program and project managers

5. Are the design structure matrices (DSM) used by engineering groups and not by project managers?

Design Structure Matrices were being used by engineering groups in the second case study but they were not used, listed or mentioned by program and project managers within the PM tools and techniques in any of the four cases (see the list of tools and techniques at the end of each case study, Ch. 4).

The DSM helped specialists to plan for activity time reductions and the resulting improved estimated time was later incorporated by program and project managers into the general project scheduling. As explained by a program manager from Company 2, "experts estimate the time to develop the task and my role is to integrate the project schedule". For instance, in Company 2 a matrix was developed by engineering groups aimed at reducing the time to develop a certain device. Once this reduction was in theory achieved, the time estimation was given to the project manager who utilised the information to integrate the project schedule.

This evidence seems to sustain the assumption that DSMs are not used by the PM community but by engineering groups and the main reason seems to be that the tool is more appropriate for improving engineering processes which is a main responsibility of the specialists. Given the exploratory nature of this research, this assumption and the reasons thereof require further confirmatory research.

The DSM technique was an important tool for improving the planning process in company 2. It might be worth to discuss the possibility of including it in the PM lexicon, at least conceptually, to foster its application amongst specialists. Soo-Haeng and Eppinger (2005: 325-fig 11) have already developed a "project management framework" that includes the DSM.

6.4 Parallel working versus resource smoothing, still an issue

6. How do managers deal with the problem of resource imbalance in a CE-type environment where overlapping is constantly applied in order to shorten the projects lead-time?

The field research showed that managers still struggle with the problem of resource imbalance. The approaches followed by practitioners ranged from intuitively assigning and balancing resources on a day-to-day basis (as in Company 4) to the use of sophisticated (and expensive) Enterprise Project Management tools (like SAP-PM in Company 2). Although the EPM integrated program information with company's financial information, it was not helping program and project managers to deal with the problem of resource congestion on a day-to-day basis. The tool was instead more beneficial for directors or executives to visualize and link key program performance indicators with the business goals.

Thus, the exploratory research suggests that it is necessary to find simpler, less expensive, yet accurate tools to assign and balance resources in multiple and concurrent project environments. To this end, heuristic solutions focusing on parallel development (e.g., Kara et al, 2001) or simulation (Bhuiyan et al, 2004) should be further investigated.

Interestingly, co-location was used in three companies to promote concurrent engineering (parallel development, convergence and work-in-team) but the practice engendered problems of resource assignment and balance. In Company 1, co-location was promoted but it was not a systematic principle of operation. Complaints regarding a lack of specialists were not heard during the interviews. The problems detected in Company 1 happened to be rather a lack of team autonomy and a hectic, meetings-based system.

Company 4 did not co-locate teams either but the members were kept within their functional departments (functionally and physically). Furthermore, the co-location approach, called "customer focused teams", had been replaced by the actual cross-functional non co-located teams. As described in chapter 4, two of the reasons for abandoning the customer focused teams system were related to resource management: firstly, "teams became resource hungry"; and secondly, "if the customer stood still, the teams had to".

The two companies that strove for co-location in a systematic way, i.e., Companies 2 and 3, reported more problems in staffing the teams because of scarce resources. Additionally, specialised resources, which were necessary for the cross-fertilisation of ideas between teams and for executing independent reviews, were not co-located, thereby increasing the "resource hungry" syndrome within them.

The companies dealing with the most complex products (2 and 3) applied co-location in each project. The company producing the simpler product (4) did not apply co-location. The company with an ample range of product complexity (1) applied co-location on a discretionary basis. From these observations it can be suggested that: the higher the complexity of the product, the higher the need for co-location. If it is assumed that product complexity is associated with information uncertainty, these contingent conditions confirm results obtained by Bhuiyan et al (2004) who found that dedicated teams are useful under high, but not low uncertainty" (Bhuiyan et al, 2004: 1701).

6.5 Two perspectives of PM and the relationship with product development

7. What is the PM scope of application in developing new products?

Results show that both the Pm execution and the PM broader perspective were being applied in the four companies. Projects in Company 1 were developed under a highly dynamic environment and projects in Company 4 were relatively small projects. These findings provide evidence that PM can be applied in small projects and projects under dynamic environments, unlike the opinion of a number of authors (Blackburn, 1991; Eisenahrdt and Tabrizzi, 1995; Krishnan et al, 1997; and Coombs, 2001).

While the Pm execution perspective was well known and commonly applied in the four companies, the PM broader perspective had different meanings and scope. Although there was evidence of MP (Management of Projects) and MbyP (Management by Projects) application, practitioners were in general using the term Program Management. Table 6-5 summarises the findings regarding program management application alongside a comparison with the most relevant characteristics presented in the literature review chapter about the two perspectives of PM.

The term "benefits management", an emergent concept in program management, did not arise during the field research. A plausible reason seems to be that this concept fits when managing "change projects" in organisations, instead of "development projects" which arise from business area strategies (Levene and Braganza, 1996: 331). Likewise, the management of "propositions" or spin-offs observed in Company 1 has apparently received scant attention in the literature reviewed on PM.

Program Management scope ranged from an overall business-orientated PM approach leading the development, as in Companies 2 and 3, to an approach that was in practice limited to the PM execution perspective, as in Company 4. This variability in scope and concept, also observed in the literature, seems to confirm the suggestion that there exists "quite a degree of confusion over what is involved in PgM" (Morris, 2004: 3).

These different dimensions of PgM were analysed vis-à-vis factors that could be contingent upon its application:

- Production volume
- Product complexity
- Size of projects and levels of innovation
- Forces driving the development

Table 6-5 Findings regarding program management and a comparison with the literature about the two perspectives of PM.

Company	Findings	PM perspective
4	*Program* was the term used to develop a new product in the automotive sector, thus, in this sense it does not differ greatly from *project*	Pm execution. Project Management and Program Management are to some extent synonymous. Archibald (1992: 24) and Cleland and King (1983: 70)
1, 2 and 3	The programs were subdivided in manageable units called projects or work packages	Pm execution. Program consists of a group of interrelated projects. PMBOK- PMI (2000: 10), NASA, 2002.
2 and 3*	Programs were explicitly linked to the business processes	MP. Projects need to be linked to business strategies. Morris, 1997, Shenhar and Dvir (2004) Thiry (2004)
1, 2, and 3	Technology and innovations were transferred among new and existing products within the program	MP. The management of the technology and the interdependencies between projects is a key issue. Thiry (2004: 246), Morris (1997), PMBOK-APM (2000)**
2 and 3	The program managers' sphere of action extended along the product life cycle	PgM. Programs are of a more steady nature as opposed to projects that have a more definite start and end. Thiry (2004: 246), NASA (2002). Programs include projects and on-going operations PMBOK-PMI (2000: 10)***
2	All initiatives should be managed as programs according to the principles of Integrated Program Management (see case study description)	Management by projects. All projects linked by an explicit strategy. Gareis (1989, 1991).
1, 2, 3, 4	No evidence was found that program mangers managed the project/product portfolio. The term "benefits management" did not emerge in any of the interviews or documents.	Portfolio management and benefits management. PMBOK-APM (2000: 1.3), Reiss (2004), OGC (2004), Blomquist and Müller (2004). The management of the Business Case. OGC (2004), PMBOK-APM (2000: 5.1)
1	A program was like a proposition or a spin-off where new products that fulfil this proposition were created along the program life cycle.	The literature reviewed did not highlight this concept

*In Company 1 the link was through the NPD process; in Company 4 the link was not explicit, it was reported to be done by business development managers

** The PMBOK-APM (2000) is a framework that represents the MP concept (see Ch. 2)

*** The PMBOK-PMI (2000) handles programs as a related endeavour only

The low production volume was a particular characteristic of Companies 2 and 3, which might have favoured the application of an extended PgM approach including production and service. PM techniques have traditionally been classified under low-volume production systems (see chapter 2). This condition helps to explain why all activities in Company 2, including series production, were defined as programs and were managed under the Integrated Program Management framework.

The high complexity of products in Companies 2 and 3 happened to be the condition that leveraged their PgM approaches into a business perspective. As will be discussed in section 6.6, highly complex products seem to require high-profile program managers (highly skilled, knowledgeable, experienced and so on).

The small size and low level of innovation, as well as the high production volume in Company 4, were factors that might explain why the Pm execution perspective[2] fulfilled their needs. As explained in Chapter 5 and the case study description of the fourth company (Chapter 4), the low level of investments along with the type of activity (highly repetitive), were conditions that required the application of a simple process adhered to the APQP. This process added structure, standardised the activities, and ensured that, through the use of checklists, the quality required by customers was targeted. Additionally, program managers handed-over the project after product stabilisation on the shop floor to production managers in charge of the production of large-volume batches.

Finally, the forces driving the development happened to be a factor that impinged on the way PgM was applied and its relationship with NPD. In this case, Company 1 was the only company developing new products driven by the market instead of by customer contracts. The main difference is that market needs may abruptly change, whereas customer needs in contract driven projects change in agreement with customers. Hence, the changing conditions of the market could have forced Company 1 to implement an NPD approach that ensured the development of commercially successful products ("to select the right product"). However, practitioners felt that the NPD approach was strategic and therefore they needed a more tactic approach. Consequently, in Company 1 the PgM approach was conceived as a complementary approach to guarantee the delivery of the most promising products ("to deliver the product right").

Both NPD processes as applied in Company 1 and PM-orientated processes as applied in Companies 2 and 3 had the same business-orientated purpose but the language utilised in the companies was different (NPD, NPI, IPM, NPM). The processes to develop new products appeared as a combination of NPD process models derived from the NPD

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[2] They use program managers and programs but it should be remembers that these terms were sectot-related.

literature, complemented by a Pm execution-orientated methodology like PRINCE 2. Alternatively, it appeared as a business-orientated PgM or IPM process based on the PM broader perspective, which broke down to PM execution procedures (as in Companies 2 and 3). These reflections might explain why PM has been considered mainly under the execution perspective by NPD authors (Wheelwright and Clark, 1992; Krishnan and Ulrich, 2001; Brown and Eisenhardt, 1995; Cooper, 2000), because NPD could be replacing the PM broader perspective.

The findings also indicate the PM broader perspective had primarily being enacted by program managers in Companies 2 and 3 developing products with the following characteristics: low-production volumes, highly complex, innovative, and driven by contracts (B to B). As expressed by a practitioner in Company 4 these projects were to some extent one-of-a-kind. In less innovative products, as in Company 4, program managers performed satisfactorily under the Pm execution perspective. In Company 1 both cases were observed. Managers mentioned that some programs were to some extent important and one-of-a-kind that program managers were requested to have business vision and multi-project management skills. During the follow-up workshop, they even mentioned that one program had been assigned to a Director. Project managers following the common practices associated to the Pm execution perspective satisfactorily developed other minor programs or projects aimed at updating product features. Therefore, as speculated in Ch. 2, it is possible that the MP (the Management of Projects) or the PM broader perspective is an approach that is more appropriate for one-of-a-kind major projects, whereas small, low-investment and relatively repetitive projects can be satisfactorily managed through the Pm execution perspective, called it project or program management.

These suggestions may help managers in the future to select the right approach for developing new products depending on the conditions of their companies and products, thereby avoiding conceptual contradictions between different functional groups as it was observed in three companies (1, 2, and 3).

6.6 The product manager and the program and project manager

8. What is the relationship between the product manager and the project/program manager during the development of new products?

The data show that product managers, business managers or business development managers[3] played an important role at the beginning of product development in the four companies. They developed the business case and handed over the project once it was authorised. Product managers reported to commercially orientated functional heads, and program and project managers to technical or operational functions. In Companies 2 and 3 product managers and program managers had a similar hierarchical position. These observations around the role and hierarchical position of product managers agree with similar studies (Luck, 1969: 33-34; Kelly and Hise, 1979: 329; Eckles and Novotny, 1984; Handscombe, 1992).

The role and hierarchical level of product managers in Companies 1 and 4 compared to program managers' contrasts with the findings explained above. In Company 4 the business development managers reported directly to the company director. In Company 1 the position of product and program managers was similar, however, the head of product managers was one hierarchical level higher than the head of program managers. As mentioned in the case study reports, the authority of both job positions (Product Management Director and Business Development Managers) was higher and they enjoyed better prestige.

The higher position of the head of product managers in Company 1 seems to be related to the forces driving the development (market-driven). As explained in Ch. 5, a strong leadership was necessary to halt the development of products which did not promise to be profitable any longer. The director of this function and the product managers reporting to him had the final responsibility for the products' return of investment while the technical director and the program managers reporting to him were only responsible for achieving the programs in time, on cost and with the required quality.

The business development managers' higher position in Company 4 compared to program managers' is difficult to explain. Business development managers were responsible for breeding new ideas, for linking new products to the business plan, and for reviewing the developments together with the Executive Team. This relatively high position and

[3] All these positions will be called "product managers" hereinafter in this section, unless otherwise specified.

relevant role reflects the importance of new products to the company. The program managers' low-profile, however, happens to indicate the opposite. They were like project coordinators, did not have a PM career and reported to the head of Quality Assurance. Besides, the position had been organizationally attached to different functional heads in a short period of time and the position of the head of program managers did not exist in the company. Unfortunately, neither the company Director nor the business development managers could be interviewed to investigate directly this contrasting situation. One likely explanation was the claim from interviewees that the company was suffering an increasing shortage of staff due to "lean" policies.

The role of the program manager during and at the end of the development varied from company to company (see Chapter 4 and 5 section 5.3.2). Program and project managers[4] were in charge of the development phase in the four companies, whereas in Companies 2 and 3 they had responsibilities beyond product launch; they monitored products during operation and service. Most of the literature reviewed revealed that project managers handed-over the product to product managers after product launch as in Companies 1 and 4. The only evidence that program managers (and not product managers) monitored products in the market after product launch was found in the heavy-weight product manager[5] role described by Clark and Fujimoto (1992). In fact, many characteristics of this role correspond to program managers from Companies 2 and 3 for example: coordination responsibility in wide areas, including production; coordination responsibility for the entire project period, from concept to customer; maintain direct contact with customers; the ability to forecast future customer expectation based on ambiguous and equivocal clues in the present market. The complexity of the products developed in companies 2 and 3 can be compared to the complexity of developing a car. This similarity might be a confirmation that the development of complex products

[4] For simplicity reference will be made to program managers henceforth, unless otherwise specified, since project managers reported to program managers in three companies and there were only program managers in Company 4.

[5] As explained in Chapter 2 although it is called "product" manager, the role corresponds to the project manager.

requires strong program or project managers as proposed by Archibald (1992) and Hobday (2000)

Nevertheless, the heavy-weight product manager described by Clark and Fujimoto (1992) had a strong influence in commercial issues, a characteristic not observed in project managers in Companies 2 and 3; the sales function was said to be the responsibility of the business or commercial managers.

Another interesting difference was the close relationship between the product managers and the program and project managers in Company 1, which was called "dual relationship". (see chapter 4). The dual relationship might have reflected the need for rapidly responding to market changes (the force driven the development). Moenaert et al (2000) also found that the nature of the market influences the organization around product development. A dual relationship between the product and program managers may represent a practical alternative to the role of the heavy-weight product manager as persons with so much technical and commercial experience are not always available.

6.7 Explaining the relationship between classification systems

9. How can it be explained that CE, NPD, and PM classification systems subsume each other?

The case studies uncovered that practitioners classified tools and techniques according to their functions, like business or commercial, engineering or PM (the tools for the program and project management functions) and not according to knowledge fields as academics have done it with CE, NPD, and PM taxonomies. Unlike typical CE frameworks appearing in the literature, practitioners from Companies 2 and 3 questioned that tools like FMEA, CAD/CAM/CAE and PDM were part of a CE framework. Furthermore, high-level abstract concepts like CE, NPD and PM were not included in the classifications developed by the companies, as appeared in the literature. These findings indicate that these extended classification systems may not be useful in practice.

The development of *all-inclusive* classification systems might be caused by competing academic communities or consulting firms extolling their approaches as the panacea and tending to minimize or ignore the others. In fact, *all-inclusive* taxonomies seem to be theoretically questionable since "a good theory is, by definition, a limited and fairly precise picture. It does not attempt to cover everything and would fail to meet the parsimony criterion if it did" (Poole and Van de Ven, 1989: 562).

On the other hand, however, the creation and expansion of taxonomies or classification systems is, by nature, a research activity (the classical example is Biology), presumably leading to "scientific knowledge" (Whetten, 1989: 492; Amundson, 1998: 342). Crawford et al (2004: 3) found that several writers considered the categorization of systems as an innate part of the human nature.

During this research it was observed that academics and practitioners tend to think and act according to their corresponding taxonomies or professional frameworks, and this perhaps inhibit the application of more integrative solutions (see examples of these barriers in the case studies 1, 2, and 3). Although practitioners did not develop their tasks by directly following CE, NPD, and PM taxonomies or frameworks, these frameworks happened to influence them. It has been observed the "immersion" of project leaders, project managers, program managers and the like into "PM bodies of knowledge", even at the level of an MSc (see case studies 2 and 3). The question is to what extent their ability to think outside these frameworks is limited. Evidence collected during the interviews suggests that this might be the case. For instance, as described in the case studies, program managers firmly believed that CE was a risky strategy, without having received formal training on CE. Likewise, specialists and product managers believed that PM was only a matter of scheduling and co-ordinating people, without having been trained on PM.

Popper's intellectual position about the "myth of the framework" seems to explain this kind of cognitive "myopia":

> One of the components of modern irrationalism is relativism (the doctrine that truth is relative to our intellectual background, which is supposed to determine somehow the framework within which we are able to think: that truth may change from one framework to another). (Popper, 1994: 33).

Foucault's Archaeology of Knowledge (1970) represents an extraordinary essay on the evolution and existence of "discursive formations", a term that might well be applied to professional communities. According to Foucault, the discursive formations are on the threshold of becoming scientific until a fundamental theory is formulated that integrates the different extant thoughts, beliefs and attempts toward theories. Furthermore:

> The analysis of discursive formations, of positivities, and knowledge in their relations with epistemological figures and with the sciences is what has been called, to distinguish it from other possible forms of the history of the sciences, the analysis of the episteme .... By episteme we mean, in fact, the total set of relations that unite, at a given period, the discursive practices that give rise to epistemological figures, sciences, and possibly formalized systems. (Foucault, 1970: 191)

Episteme in this sense can be viewed as the total relationship of theories, body of knowledge, standards, and classification systems that underpin the development of a knowledge field.

The analysis of the *episteme* might help to explain why the development of frameworks is so essential to professional communities: these frameworks might represent a means to an end or intermediate steps in pursing a scientific status.

6.8 Understanding cause effect-relationships and a likely order of implementation

10. What is the cause-effect relationship, if any, between CE, NPD, and PM?

Evidence from three companies indicates that PM impinges on CE in at least two different forms: as a change management agent to implement CE-type projects and as a driving force to foster CE practices. Conversely, the application of CE principles and techniques produce better project results which in turn might produce better NPD performance.

CE practices were implemented to enhance product development processes (more clearly in Companies 2 and 3) and PM facilitated these tasks. A program manager from Company 3 expressed this influence in the following terms (reproduced from Ch. 4): "You could apply project management as a tool to help deliver a concurrent engineering aspect of an overall project or an overall programme to introduce a new product". This "delivering" view of project management relates the Pm execution perspective and confirms its positive influence on CE implementation projects (Eversheim, 1990; Ainscough et al, 2003; Pawar et al, 2002; Abdalla, 1999; Levene and Goffin, 1997). Thus, it is reasonable to propose that the better the Pm execution practices used by the CE project implementation teams, the higher the possibilities for implementing successfully CE-type projects which in turn enhances product development (Figure 6-1).

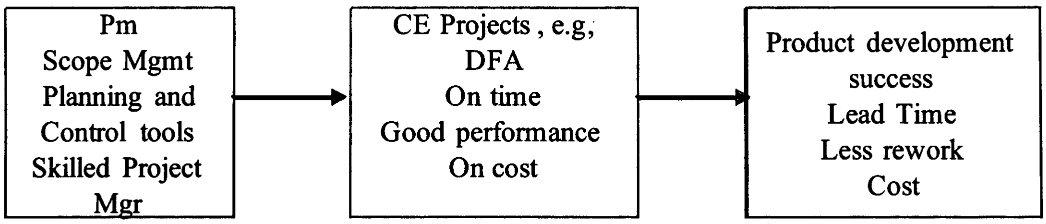


Figure 6-1. A cause-effect relationship between PM and CE

This result implies that companies launching CE initiatives may consider a training program on Pm for the CE-implementation teams and the selection of a skilled project manager to lead the efforts.

Pm could also be a driving force to foster the application of CE practices once they have been implemented. As described by project and program managers in Companies 2 and 4 the project manager might compel (or inhibit) project teams, “against their natural inclination”, to address simultaneous problem solving, to join together early-on in the project, or to enhance communication. Project and program managers certainly believed that leading projects within CE environments required additional coordination efforts than in traditional (sequential) form (see case study 2); however, they also considered that the benefits outweighed this particular exigency.

CE-implementation projects were not observed in the case studies, but it was commented by practitioners that these projects required strong leadership and executive’s commitment. The researcher experienced a CE-implementation project before starting this research where the APQP and DFX techniques were implemented. In that project, the close and frequent communication between the project “champion” and the plant manager was a paramount. Haque and Pawar (2001) presented a case study where process modelling was implemented within a broad CE initiative. Although the project was finally implemented, the selection of a strong project manager emerged as an opportunity area for the next coming CE initiatives. The authors put it in the following words:

> The team leader/project manager needs to be committed full time to that project or at least have plenty of time allocated to the task of project management and be a strong leader. In the collocated project under investigation a design engineer was

> chosen to manage the project, but was also still responsible for the design of the product. This resulted in weak project management and not enough time could be allocated to leading and managing the team, especially in the most critical early phases of the project, when design activities were at peak. (Haque and Pawar, 2001: 37).

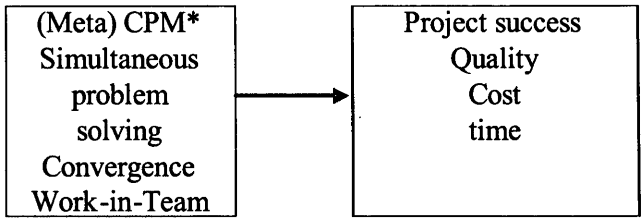
Hence, the evidence gathered in the field, the literature and the researcher's experience suggest that heavy-weight project managers may be required for implementing CE-type projects as Koufteros et al (2002) found.

On the other hand, however, project managers, project leaders and work package managers, and not necessarily high-profile program managers, led product development teams that were already applying CE (companies 2, 3, and 4). They fostered teams to solve problems simultaneously, to increase their level of communication and to join the teams early in the project (company 4). In these cases practitioners did not express claims that high-profile project managers were needed for the successful operation of the teams.

As heavy-weight project managers might be scarce in the companies, the findings suggest that heavy-weight project managers be assigned to lead CE-implementation type projects whereas low-profile project managers be assigned to lead multidisciplinary teams developing products under an on-going CE-type environment. In both cases a CE training program to understand the goals, main tenets and benefits of CE seems to be important.

As observed in the field a number of CE techniques did not happen to impinge directly on project and program managers but on the engineering functions, for instance, DFA, DFM, CAD/CAM systems, FMEA, simulation and modelling. Therefore, these specialised techniques might not be considered part of the training program other than perhaps a brief review.

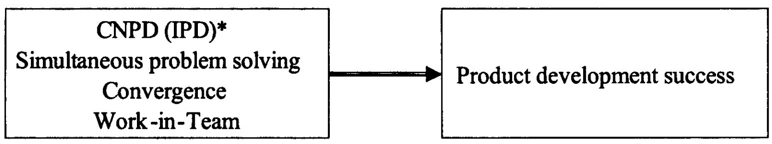
A causal model reflecting the influence of CE on PM through training programs can be seen in Figure 6-2. This model helps to understand why a combination of CE and PM has been dubbed by many as "Concurrent Project Management" (Skelton and Thamhain, 1993; Lewis, 1995; Lautier, 1996; Charue-Duboc and Midler, 2002). This model suggests that it might be worth to discuss the convenience of incorporating CE principles into the PM body of knowledge.



* Concurrent Project Management

Figure 6-2. A cause-effect relationship between (meta) concurrent project management and project success

A similar relationship (Figure 6-3) was sketched to try to explain why authors have considered CE as the new approach to product development dubbing it "Concurrent New Product Development" or "Integrated Product Development" (Khury and Plevyak, 1994; Pawar et al 1998; Gerwing and Barrowman, 2002; Büyüközkan et al, 2004). In this case, product development success criteria was thought to be different than the criteria used to assess product development *project* success as in the previous model (Figure 6-2). Tatikonda and Montoya-Weiss (2001), for instance, differentiated market success (product development success) from operational outcomes (project success). Product development success is measured through "profitability" by Koufteros et al (2002). Brown and Eisenhardt (1995) relate product development success with financial performance, e.g., profits, revenues, market share.



*Concurrent o Integrated New Product Development

Figure 6-3. A likely cause-effect relationship between concurrency and product development success (not enough evidence to support it)

Thus, while many practitioners commented that CE was helpful in improving product quality, and reducing rework and lead-time, they did not relate it with company's profitability, market share, ROI or similar indicators. Probably they were not involved in that kind of evaluation or perhaps the companies did not have mechanisms to measure the relationship, as recognised by a Senior Program Manager in Company 1. Therefore, there were not enough evidence to support a positive and direct relationship between CE and product development (financial or commercial) outcomes and the model represented in Figure 6-3 could not be confirmed.

A generic cause-effect model is proposed to explain the relationship between CE, NPD and PM and project and product development success (Figure 6-4). The model suggests that the application of meta-concurrent[6] project management practices and advanced CE type techniques may improve product development project success, and this in turn may improve product development or PM success. Both project and product development outcomes depend on internal and external factors already considered by the NPD approach or the PM broader perspective. This model agrees in general terms with other models already discussed (Koufteros et al, 2002; Tatikonda and Rosenthal, 2000; and Tatikonda and Montoya Weiss 2001).

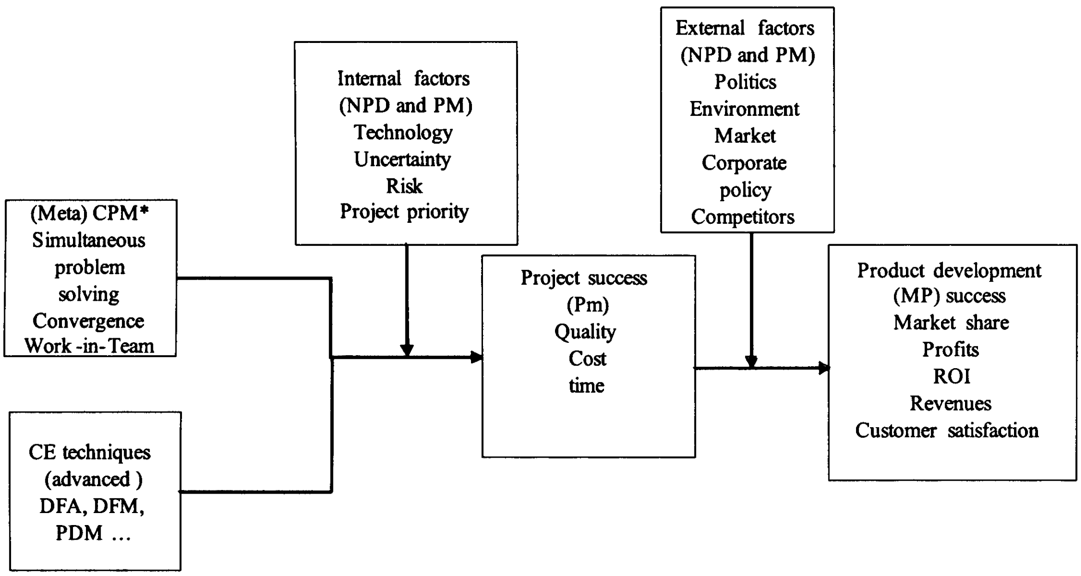


Figure 6-4. A generic causal model to understand the relationship between CE, NPD, and PM

The generic causal model (Figure 6-4) and the chronological order in which the three approaches were implemented in the companies (see 5.5) helped to outline a general schema that illustrates which approach could be a precursor to the other (Figure 6-5).

[6] As defined in 6.1

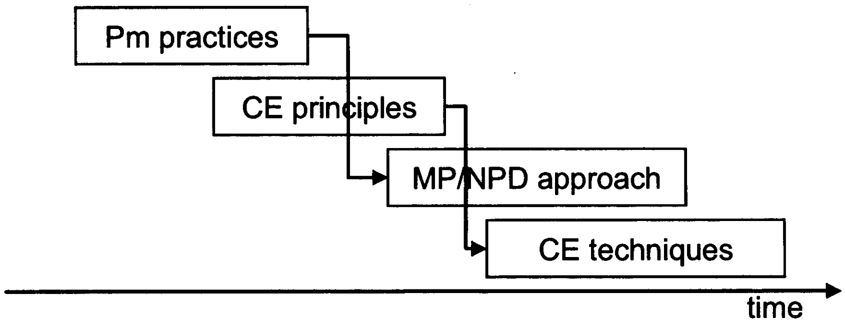


Figure 6-5. A likely order of implementation

Pm practices could be implemented first and after that the main CE principles. Then these practices might evolve towards an NPD or PM business-related framework while more specialised CE techniques are being applied alongside. The proposed sequence may represent a helpful guide for managers in deciding about the likely order of implementation and their priorities. Similar models addressing the order in which the approaches could be implemented were not found in the literature. Therefore, it could be an original contribution worth to be tested in future research.

6.9 Aligned processes

11. When should the project manager and the project team be engaged and disengaged during the process to develop new products?

The NPD, PM and Engineering processes observed in the companies were asynchronous, that is, they did not start and end at the same time. Product managers, program and project managers and specialists (part of the project team) were engaged and disengaged at different points throughout the project life cycle. In general, it was observed that program managers were engaged in the project before project authorisation and in some cases after project closure which tends to confirm the application of the PM broader perspective. The process patterns developed in section 5.3.2 provide a detailed picture of this process asynchrony and enrolment. These details are normally absent in the literature (Maylor and Gosling, 1998: 71) and are therefore considered valuable for managers to assign and release resources according to the phase of the project.

The process pattern illustrated in Ch. 5 was analysed and contrasted with the funnel model developed by Wheelwright and Clark (1992) which is one of the most cited process models for developing new products, albeit it does not seems to clearly indicate the starting and ending point of PM (see Ch. 2 for the description of the model and this likely flaw).

The first contrasting issue is that the funnel model contains three elements which were not considered by practitioners as part of the product development process in any of the four companies: market and technology assessment, the development of goals and objectives, and the aggregate project plan. However, these elements were considered in other processes, which were dubbed by the companies as strategic processes.

In Company 1 the development of long-term product strategies, product portfolio, and aggregate project plans were part of a process owned by the head of Product Management and not by the Head of Product Development. In Company 2, the medium and long term plans were developed through a process called "Plan the Strategy", owned by the Finance Director. In Company 4 the business plan and long term strategies were developed by the Executive Team and the business development managers were responsible for the alignment of the programs to these strategies. This issue could not be investigated in Company 3.

The differences in the planning horizon and in the nature (strategic and operational) of the different processes mentioned above suggest that the funnel model may be better understood at different levels of analysis or as a *multi-level funnel* as displayed in Figure 6-6.

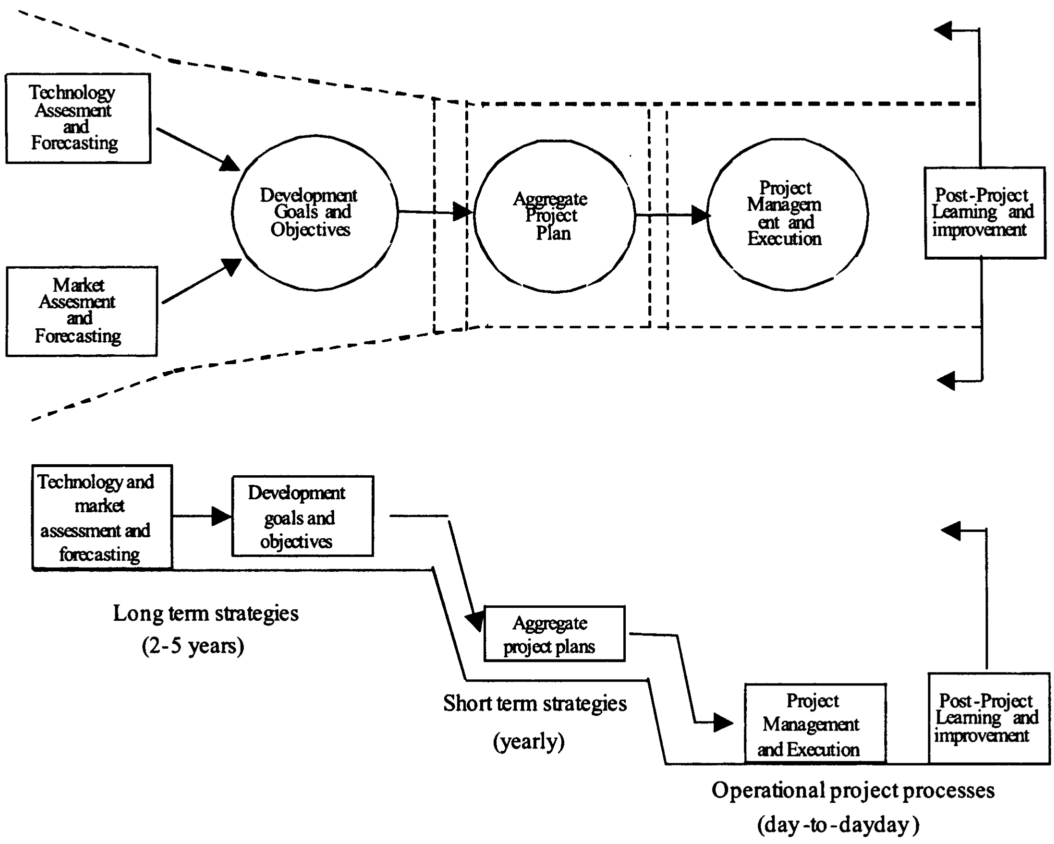


Figure 6-6. Three temporary levels of analysis in the Wheelwright and Clark's funnel model to develop new products

As illustrated, there are long-term strategic processes where the companies decide the product portfolio based on the business mission and goals. These processes are carried out every three to five years (according to the companies surveyed) and reviewed periodically. At the beginning of every year, short-term strategies are settled to formulate the aggregate project plan, in which the different products from the portfolio are developed. Finally, the so-called operational project processes are carried out by the teams on a project-by-project basis.

The second relevant research issue was that Wheelwright and Clark's model does not seem to explain clearly when PM starts and ends. Thus, by using the concept of *aligning schemas* and the process asynchrony patterns depicted in Ch.5, a modified funnel model can be proposed to more clearly understand the PM participation. The modified multi-level funnel model is shown in Figure 6-7.

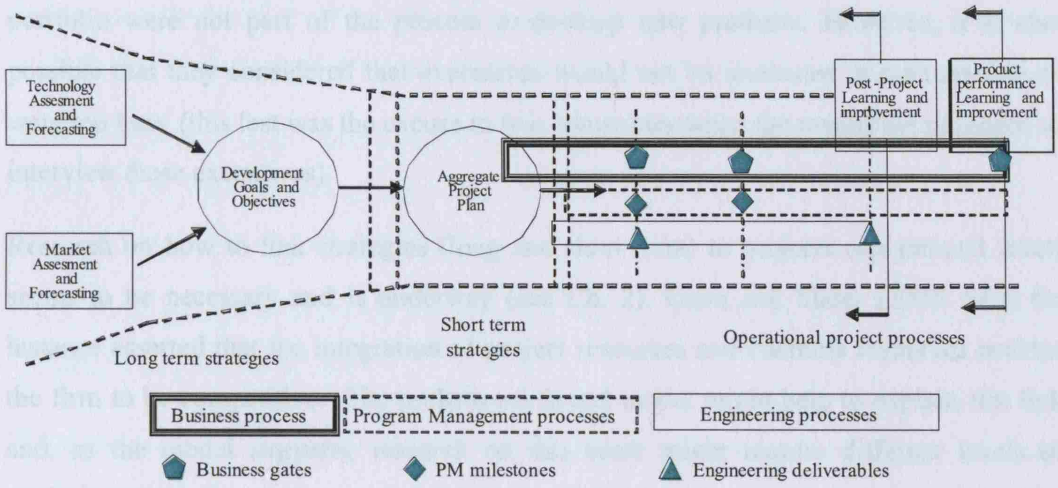


Figure 6-7. Multi-level funnel model to manage product development

The modified multi-level funnel model suggests that product and business managers and program managers should be engaged in the development before project execution and not only after project authorisation as Wheelwright and Clark's model happens to suggest (although it is not clear). At the other end of the development, program managers might be involved even after product launch (depending on several conditions) as observed in Companies 2 and 3 and as suggested by a program manager from Company 4. They should be monitoring product performance once the product is in the market or in customer's facilities in order to extend the learning and improvement cycle proposed by Wheelwright and Clark beyond a post-project stage. The modified funnel model suggests that the PM broader perspective takes a broader role in developing new products starting before project execution and finishing beyond product launch.

There was no evidence confirming the participation of program managers in the definition of long-term strategies or in the product portfolio. According to Wheelwright and Clark (1992) these are decisions to be taken by the executives which in the companies surveyed were two or three hierarchical levels above program managers. This evidence calls into question the participation of PM in the development of the product portfolio and its link with the business strategies. Program mangers in the companies that were coordinating the interviews did not include informants from these strategic processes probably because these managers considered that long-term strategies and the creation of the product portfolio were not part of the process to develop new products. However, it is also possible that they considered that executives would not be interested in participating or were too busy (this last was the excuse in two companies when the researcher proposed to interview these executives).

Research on how to link strategies (long and short term) to projects (operational level) seems to be necessary and is underway (see Ch. 2). Gann and Slater (2000: 969) for instance asserted that the integration of project resources and business resources enables the firm to be competitive. The multi-level funnel model might help to explain this link and, as the model suggests, research on this issue might require different levels of analysis and the temporary separation between them.

12. Is the APQP a suitable and complete model for developing new products because it combines CE, NPD, and PM elements?

Empirical evidence from Company 4 (Ch. 4, section 4.4) suggests that the APQP is a suitable model for developing new products. It was also observed that it combines CE, NPD, and Pm elements. This suggestion is consistent with the literature reviewed (APQP, 1994; Al Ashaab, 1999; Elsmar, 2003; Bobreka and Sokovicb, 2005; Bell and Becker, 2001; and Gruska and Cherry, 2005). However, it seems to be devoid of mechanisms to link projects to the business goals of the organisation.

Company 4 applied a single-process approach called the Design, Development and Introduction (DDI) process which was in turn closely related to the APQP standard guide. Clearly, the characteristics of the company differed from Companies 1, 2, and 3. For example, the products were simpler and less innovative, the company was smaller, and fewer products were being developed at the same time. It could be assumed that the simplicity of the DDI-APQP fitted the relatively simple structure of Company 4.

The weakness of the APQP standard guide seemed to be the lack of the necessary mechanisms to link projects to business strategies and goals. This gap had been identified and solved by managers in Company 4 and then incorporated into the DDI (see case study 4).

The APQP was developed and proposed by the "three big" American vehicle manufacturers, Ford, General Motors and Chrysler, as a standard to be applied by its suppliers (APQP, 1994). Thus, it is reasonable to assume that these three companies were mainly concerned with the standardisation and improvement of their supplier's processes, rather than with their supplier's business goals.

Unlike the opinion of different authors (Thisse, 1998; Bell and Becker, 2001; Gruska and Cherry, 2005), practitioners claimed that more should be done to reduce the bureaucratic nature of this quality management guide.

13. How can the relationship between CE, NPD, and PM be explained through interlinked process models?

Three companies (1, 2, and 3) defined and applied interlinked processes to develop new products (see 5.3.1) which were connected through common review points along the project life cycle and displayed on *aligning processes schemas*. These schemas displayed the relationship between NPD, PgM, Pm and Engineering type processes (see 5.6.1). Moreover, other processes were also aligned like supply chain and production readiness. The APQP process model applied in Company 4 was also a representation of these kinds of schemas (see Figure 2.28). These findings suggest that the relationship between NPD, PM and other processes interacting along the product life cycle can be explained through interlinked process models.

However, unlike NPD and PM, CE processes did not appear in the companies' aligning processes schemas and CE procedures describing step-by-step instructions were not found either. Rather, practitioners affirmed that CE was "embedded" in engineering processes or that CE was a form of doing these processes (e.g. in teams or through overlapping). This evidence and the lack of process models in the literature showing CE as a process suggest that, unlike different opinions (Thamhain, 2004; Bowonder et al, 2004), CE is difficult to be perceived as a process in strict sense (a series of steps bringing about a result).

Little was found on aligning schemas to correlate processes to develop new products. Evans and Juke (2000) researched aligning processes between a vehicle manufacturer (VM) and its suppliers. They elaborated "co-development maps" to synchronise processes, however, given the paucity of supporting literature, the researchers called for further research on the subject.

Tennant and Roberts (2003) developed research aimed at creating a self-assessment process based on the principles of Hoshin Kanri – policy deployment for new product introduction (see Ch. 2). The authors developed criteria for product development best practices, two of which reveal the importance of alignment: "integration of product introduction process and project/program management", and "link between major phases". Moreover, their self-assessment procedure to assess NPI practices included the following question: "how does the company ensure harmonisation between the product introduction process and other business milestones?" The authors did not elaborate on this subject but it is believed that the concept of harmonisation is consistent with aligning schemas.

Shenhar (1998:35) asserted that "any project execution involves linking two different, though not disjointed, processes along the various phases of the project's life cycle". According to the author, one process involves technical activities and another involves managerial activities. As observed in the companies more than two processes were involved and the managerial process was the umbrella under which the other technical processes run (see for instance section 4.3.3 and Figure 4-4).

6.10 Essence, purpose, and theoretical basis

Practitioners in general explained how CE, PM, or NPD worked, e.g., "(CE) is about designing the bits ...", "(PM) is doing the things right", or "NPD is doing right things" (see Chapter 4). However, they did not postulate essential definitions, i.e., whether they were *approaches, processes* or the like. In fact, the expectation was not to obtain from practitioners theoretical but practical answers as "it is not the managers' responsibility to form the abstraction but the researchers'" (Mintzberg, 1979: 585). From this practical information or raw data the process of induction shaped concepts that happen to fit and work (Glasser and Strauss, 1996). The distilled concepts were then connected to formulate propositions which were iteratively triangulated with the extant literature and researcher's intuition, i.e., assumptions, judgment, and past experiences (Lewis, 1998). The emergent concepts and propositions gave plausible answers to the next research questions which were formulated at a higher level of abstraction than the previous ones.

14. How can CE, NPD, and PM be essentially conceptualized so that they can be comparable?

As reported in Ch. 2, CE, NPD, and PM have been conceptualised differently, for example as knowledge fields, as methods, as processes, as techniques or even as philosophies. The following explanation selects some of these concepts and definitions and proposes new ones for the sole purpose of achieving a better understanding of the relationship between them. These concepts (arising from the iterative triangulation of data) do not necessarily preclude or reject others appearing in the literature, unless otherwise specified.

The field research confirmed the appreciation of some authors that CE is not a single approach, but a multitude of approaches (Pawar et al, 2002, Veness et al, 1996). These approaches seemed to be embedded in technical procedures, developed by multidisciplinary teams, and involving the application of info-tonic[7] type tools and techniques like CAD/CAM, DFX, and PDM. Its main benefit happened to be the improvement of product quality and the abatement of rework, which leads to shortening the lead-time. None of the companies had launched an approach, project or initiative called CE. Many papers also reported how CE-related approaches were implemented like QFD (e.g. Abdalla, 1999), process modelling (e.g., Pawar et al, 1999), or PDM (e.g. Baake et al, 1999), but papers describing how CE initiatives were implemented were not found. Even the influential Winner et al's report, (1988) presents examples of companies who have implemented CE-related techniques like Taguchi methods, process management, and Product Development Teams (see Winner et al, 1988: Apendix A: Case studies).

These references and the field research suggest that CE might essentially be conceived as a *status* to be reached: a status where many improved engineering practices are present so that the excellence is achieved. This view of CE may be similar to the concept of *environment* mentioned by Ellis (1992) and Thamhain (2004), or *philosophy* as conceptualised by a manager in Company 3 and by authors like Jo et al, (1991) and Skalak et al, (1997). CE is closely related, or perhaps embedded in Total Quality Management (Prasad, 1997; Gunasekaran, 1998; Gerwin and Barrowman's 2002). This conceptualization may explain why CE frameworks include PM and NPD: because they can certainly be viewed as methods aimed at improving the engineering of a product. CE,

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[7] Tools that combine informatics and electronics

in this guise, happens to be an ever-evolving program, as it can be TQM, Lean Manufacturing (Narasimhan et al, 2006) or Just in Time (Cua et al, 2001).

These findings and reflections might be interesting for managers that have implemented or try to implement CE. The field research showed, specifically case studies 2 and 3, that CE required investments, commitment, motivation and vision. It did not happen to be an approach that started and ended in a short period of time.

Winner et al discussed "what CE is not" (Winner et al, 1988: 21-22) and these negation principles were analysed to verify the consistency with the data and with the discussion above:

"CE is not a magic formula for success". Consistent: it involved a rather a series of improvement projects that in conjunction lead to a status of excellence.

"CE is not the arbitrary elimination of phase of the existing, feed forward engineering process". Consistent: no evidence or explanation was given to suggest this possibility.

"CE is not simultaneous or overlapped design and production". Consistent: the findings and concepts proposed in this thesis indicate that simultaneous development is only a partial view of CE.

"On a somewhat less dramatic, but equally important note, CE is not just design for producibility, or design for reliability, or for maintainability. CE includes all these with the added requirement that the objective is for the design optimization...". Consistent: it entailed a variety of approaches aimed at optimizing engineering (excellence).

As discussed in detail in section 6.9 the results suggest that it is difficult to perceive CE as a process or a series of steps bringing about a result, as has been conceived by other authors (Thamhaim, 2004; Bowonder et al, 2004).

NPD was essentially seen a managerial activity employed to filter ideas to ensure the commercial success of the products. It consisted of a product portfolio, a business or commercial gated process, and sales and marketing operations to ensure successful product launch. In the experts' words from Company 1, it was the approach to select the "right product". It was the framework that supported the tasks of product managers in Company 1 and the umbrella process under which other processes run. This evidence confirms the notion that NPD can be viewed as a process (Cooper, 1994; PDMA, 2003a).

The field study confirmed that PM can also be conceptualised as a *process* (CRMP, 1999; PMBOK-PMI, 2000). The four companies applied PM processes to develop new products where the main difference was the level of the process, i.e., tactic or strategic. In Company 1 the PM process was considered a methodology (PRINCE 2) to deliver the project right and in Company 4 the PM process was seen as a procedure adhered to a standard. Hence, the perspective in these two companies happened to be the tactic Pm execution perspective. In Companies 2 and 3 the process was considered a business process and a more strategic PM broader perspective was apparently in place. This finding agrees with Winch (2000) who proposed leveraging PM as a strategic business process. Aligning schemas and process maps were found in these companies as practical mechanisms to relate broader NPD or PM business processes with Pm execution processes.

PM was found to be also a *career* in three of the companies through which project managers might advance up the hierarchical ladder of the company, that is, from work package manager (as in Company 2) through to project director (as in Companies 2 and 3). Jones (1996) affirmed that "a career provides an occupational identity" and therefore, this finding supports the view of PM as a professional *discipline* (Morris, 2002 and Bredillet, 2004) or at least as a "semi-profession or emergent profession" (Morris et al, 2006).

In Company 4 PM was not clearly recognised as a *career*. There was not a hierarchical ladder to ascend to by program managers (their head was the Quality Assurance manager), no training on PM and, despite the name, program managers were rather full-time project coordinators. The small size and relatively simplicity of their projects suggests that the role of PM would depend on the size and complexity of the projects. This proposition would then confirm that PM cannot be viewed as a professional occupation (Zwerman et al, 2004) as professions in general do not depend on size or complexity (a doctor is a doctor regardless of the seriousness of the illness). Since the proposition can be falsifiable by assuming that Company 4 did not have good PM practices, the door remains open to investigate the PM scope in companies or institutions successfully developing small or *minor projects*[8].

There was no evidence suggesting that CE and NPD were also considered as careers in the companies. This fact is consistent with CE literature which does not present any framework through which professionals could be labelled or certified as *concurrent engineers* or similar. Concerning NPD, the PDMA do certify Professional Product Managers (see chapter 2) but certified NPD professionals were not found amongst the people interviewed.

15. What is the difference in purpose, if any, between CE, NPD, and PM?

At the beginning of the Literature Review chapter, each approach was described using an opening sentence that might summarise their purpose: "(CE) Managing the engineering concurrently…"; "(NPD) Managing an innovation …"; "(PM) managing a project …". In all three cases "managing" is the common subject, the difference arising in the object: *the engineering concurrently*, *an innovation*, *a project.*

Managing the engineering concurrently implies that it is possible to manage engineering in a way other than concurrently, perhaps sequentially or simply *not concurrently,* that is, the essence is *how* the engineering should be managed which implies that CE represents a *know-how*.

Managing innovation and managing projects implies managing *something* or managing *what.* Therefore, NPD and PM could be seen as *know-what.* Further, an innovation and a project can be managed concurrently which explains the adoption of terms like Concurrent Project Management or Concurrent Product Development. Likewise, managerial processes can be managed concurrently as it happened with the New Product Management (NPM) process in Company 2 and the New Product Introduction (NPI) process in Company 3.

The Pm execution perspective was also be perceived as a *know-how* (by most people in Companies 1 and 4 and by specialists in Companies 2 and 3). This ambivalence of PM

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[8] As opposed to *major projects* which have been studied by Morris and Hough (1987) and confirmed the relevant position of PM in these kinds of projects.

helps to explain why PM and NPD were apparently clashing in Company 1. For some managers the NPD was a "high-level" PM process, while for the others PM or PRINCE 2 was a "delivery" or know-how sub-process embedded in the "high-level" NPD.

The most important suggestion drawn from the data and the literature review could be that companies must know *what* to do and *how* to do it, regardless of the language used (called it NPD, MP, PgM or anything else). While it has already been recognised that PM is a know-what and know-how (Morris et al, 2006), it is argued here that this ambivalence is not easily understood by practitioners which in general seems to prefer straight-forward clearly defined approaches or prescriptions (Bazerman, 2005). This might explain the rapid development of Pm execution type frameworks like the PMBOK-PMI (2000) in the USA.

It is important to research in the future the difference between managing the innovation, a project, and the engineering. It seems to be necessary to propose in which cases "innovation" and "engineering" can be considered projects. In such a case, PM would be *the approach* to manage the innovation and the engineering. However, the literature review shows that innovation management and engineering management have different approaches and sometimes NPD and CE authors underestimate or even ignore PM.

Innovation and engineering might be processes rather than projects. This difference could be the reason for relatively independent fields of research, methods, frameworks, and even independent communities of practices. Perhaps it is worth to recalling the opinion of a manager from Company 4 who mentioned that in the automotive industry a project was more "experimental" or unique whereas a program was considered a structured way to go from concept into production on a repetitive basis. If it is considered that programs in Company 4 were highly repetitive and PM was applied on a basic level, whereas in Companies 2 and 3 projects represented unique efforts and PM was applied to a greater extent, one is tempted to propose that the more repetitive the projects the greater the need for process management, or that the less repetitive the project, the greater the need for PM.

In this respect Brusoni et al (1998) and Gann and Salter (2001: 957) argue that "in general, business processes are ongoing and repetitive, whereas project processes have a tendency to be temporary and unique". Studies dealing with these topics (differences and similarities between project and process management) have already been started (e.g., Nicholson and Sieli, 1990; Dowson, 1991; Adler et al, 1995; Shih and Tseng, 1996) and the questions emerging in this research seem to confirm that more should be done to clarify this issue.

The main benefits of CE, according to practitioners, happened to be better product quality. Interestingly, many readings on CE assert that satisfying customer need is one of the main goals of CE. However, this benefit was barely mentioned by the practitioners in the different companies. Probably the reason was the lack of a homogeneous understanding of this approach.

The most common benefits of NPD and the PM broader perspective according to practitioners were the achievement of "visibility" across the process, the focus on commercial or business aspects, and the orientation towards customer requirements (see Table 5-10). As mentioned by a program management from Company 3 the NPM was a process to add structure across the different company facilities allowing people "to get things done". Readings on NPD agree on these aspects and the literature on the PM broader perspective (MP, MbyP and PgM) is increasingly focusing on these strategic issues of product development.

Pm was reported to be the main "engine" to drive the ideas or customer specifications towards products ready to be produced. As emphasised in Company 1, it was the approach to develop the right products. NPD or PM frameworks were complemented with Pm tools and techniques and with skilled program or project managers able to take decisions when deviations occurred along the project life cycle. Program and project managers had to be able to lead project teams and, as in companies 2 and 3, to work concurrently for better results.

These particular differences regarding benefits (summarized in Table 6-6) may help managers to choose the right approach according to their needs or to improve their actual product development practices.

Table 6-6. CE, NPD, PM broader perspective, and Pm distinctive benefits

Concurrent Engineering	**NPD or PM broader perspective**	**Pm**
Better product quality	Business visibility Customer focus	Getting the right products

16. Do CE, NPD and PM have different levels of maturity?

Maturity may mean different things for different people. A definition from the dictionary describes it as the "state or quality of being fully grown or developed". In organizational terms, the concept became familiar when the Capability Maturity Model (CMM®) was developed in Carnegie Mellon both as a means of assessment and as part of a framework for improving software quality[9]. Recently, (Organizational) Project Management Maturity Models[10] have also appeared and they are supposed to be used to measure and progressively improve PM practices.

In Ch. 2 the term maturity was also used in reference to CE, NPD and PM growth but from an ontological and epistemological perspective (e.g. the self-questioning of the field, the methods used, and the research trends). In this sense, the Kuhnian concept of paradigm helps to define more accurately maturity and facilitates the comparison between CE, NPD and PM. According to Kuhn:

> The members of all scientific communities, including the schools of the "pre-paradigm" period, share the sorts of elements which I have collectively labelled 'a paradigm'. What changes with the transition to maturity is not the presence of a paradigm but rather its nature. (Kuhn, 1970: 179)

From this assertion Lodahl and Gordon (1972) inferred a continuum of degrees of scientific development in terms of paradigm development. Paradigm development was broadly defined by the authors as the level of consensus in the nature of knowledge, methodologies and research topics created and shared by any given professional or scientific community. Kaghan and Phillips (1998) related paradigm development and maturity suggesting that the more mature the science is the higher the level of its paradigm development.

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[9] http://www.sei.cmu.edu/cmm/, accessed in July 2006.

[10] For instance the OPM3® from the PMI® (http://www.pmi.org/info/PP_OPM3.asp) accessed in July 2006, and PMMM[SM] from PM Solutions (http://www.pmsolutions.com/maturitymodel/whatismodel.htm), accessed in July 2006.

Pfeffer (1988) reviewed different methods that researchers have used to operationalise and measure the level of paradigm development:

- The proportion of PhD graduates employed in college or university teaching.
- The percentage of references in published works that were themselves published in the preceding five years.
- Paradigm consensus. Less time spent defining terms or explaining concepts. Or accepted and shared vocabulary. These ideas led to the use of length in dissertation of abstract (in words) and length of dissertation (in pages).
- The length of the longest chain of courses in a department, where a chain is defined as a course being a prerequisite of another course.
- The preference for and use of graduate students and assistants in the research process.
- Journal rejection rates (the higher, the less paradigm development).
- Review times of papers in journals (the higher, the less paradigm development).
- Cross citations. Citations in low paradigm fields come from fields that are more paradigmatically developed.
- The proportion of publications in a field in the form of articles rather than books.

The criteria above and the experience gained in this research leads to speculate that NPD might have higher levels of paradigm development (and therefore maturity) than CE and PM. Additional criteria were investigated to explore this possibility.

Pfeffer (1998) suggests that doctoral studies in the social sciences take, in general, more time than in the natural sciences because the former lack consensus and shared vocabulary. He then quotes Zammuto and Connolly referring to doctoral students in the social sciences.

> They are confronted with a morass of bubbling and sometimes noxious literature. This lack of agreement leads to difficulties in doctoral training, including high rates of attrition, a long period of time needed to complete the degree, and problems in training doctoral students in distinguishing good from bad theory and methods. (Pfeffer, 1988: 612)

As a doctoral student, the researcher of this thesis found that NPD literature has a higher level of consensus, shared vocabulary and detailed information when compared with CE. As commented previously in this thesis, CE definitions, concepts and methods are so dispersed that the effort to set a common framework or to identify topics for further research was considerably high. With regard to PM, the level of consensus should be judged again from the two different perspectives. The literature on the Pm execution perspective exhibited so high levels of consensus in the basic tenets and a shared vocabulary that one tends to think that there is nothing else to research. However, in the PM broader perspective the level of dispersion in the incipient literature is considerable up to the point that different names have been proposed to more clearly encompass its greater scope (e.g., the management of projects, management by projects or program management). From this broader perspective, PM might be at the same level or close to the level of dissension as CE.

Kuhn sustains that, debates among members of a community regarding the ontology and epistemology of the knowledge field evidence a pre-paradigmatic period (Kuhn, 1970). In this respect, more studies were found in the PM literature analysing (and criticising) past and present research and proposing agendas for future research, as well as questioning the lack of underlying theories to unify thinking in the fields (see the Literature Review chapter). NPD literature might be situated in second place regarding this kind of analysis and questioning the true nature of the field. CE studies on past, present and future are scarce (only two were found, namely Lettice et al, 2004, and Wognum et al, 2003), and only one questioning the "limited awareness about theories of science and research methodologies" (Lettice et al, 2004: 135). Therefore, based on introspective studies found in the literature, it is possible that the PM community is more clearly experiencing a pre-paradigmatic period (followed by NPD and then CE). This suggestion has also been introduced by Bredillet (2004).

Foucault's Archaeology of Knowledge (1970) reveals that fundamental theories constructed by great theoreticians like Freud and Darwin catapulted Psychology and Biology to cross the threshold that exists between discursive formations and sciences. Likewise, in Kuhn's classic "The Structure of Scientific Revolutions" (Kuhn, 1970) one can confirm that great theoreticians (epistemological figures) like Copernicus, Newton, and Lavoisier, started revolutions that gave rise to new paradigms.

Comparatively speaking, great theoreticians whose work had given rise to CE, NPD, and PM were not identified during this research. Morris, in relation to PM, affirmed that "there is not yet a popular guru or a strong intellectual voice recognized by the managerial curious 'man in the street' on either side of the Atlantic ... It will come." (Morris, 1977: 310). These "popular gurus" have probably appeared in cognate disciplines. For instance, few people would question nowadays the contribution of Deming, Juran, and Ishikawa to the formation of Total Quality Management (TQM) (Hackman and Wageman, 1995; Handfield and Melink, 1998). Therefore, it is speculated that CE, NPD, and PM, are still expectant for the development of a big theory (and for great theoreticians) that unifies the thinking of the professional communities and marks their transition to a new epistemological position. Nevertheless, this transition might never happen, as it did not happen with medicine, engineering, and astrology which were identified by Kuhn as "crafts or practical arts" (Kuhn, 1970: 8).

Highly developed paradigms have achieved consensus regarding research methodology and techniques (Kuhn, 1970; Lodahl and Gordon, 1972). Lettice et al (2004: 135) observed the methodical weakness of the CE papers submitted during the 10 years of research conferences where "a high proportion of the papers are theory without validation or tool design without application or validation". Wognum et al (2003) stressed the need for more empirical research on CE. Similarly, PM researchers complained about the lack of empirical research on the subject (Pinto, 2005; Shenhar, 1998). Moreover, Shenhar and Dvir (2004: 7) claimed that "to gain recognition and establish itself as an attractive field of research, PM needs more coverage in prestigious journals", amongst others the Academy of Management Review[11].

Assuming that publication in "prestigious journals" improves the quality (empiricism) of research and in turn the level of paradigm development, a simple test was carried out: the level of "prestige" of representative journals was explored. "Prestige" in this case was operationalised through the Impact Factor of the Journal Citation Report ® of the ISI Web of Knowledge (as accessed in October 2005). Highly cited papers have a high probability of "having advanced new paradigms" (Forsund and Sarafoglou, 2005). The

[11] Several other names were given by Shenhar in his speech (they do not appear in the paper).

results are shown in Table 6-7 where the impact factor of the Academy of Management Review Journal is displayed for comparison purposes.

Table 6-7. Impact factor[12] in 2004 of representative CE, NPD, PM and management Journals.

Journal	Subject covered	Impact factor
Concurrent Engineering Research and Applications (CERA)	CE	0.418
Journal of Product Innovation Management (JPIM)	NPD	0.885
International Journal of Project Management (IJPM)	PM	Not listed
Project Management Journal (PMJ)	PM	Not listed
Academy of Management Review (AMR)	Management, Organisational Studies	3.717

As can be observed from the table, the JPIM had a higher impact factor when compared with CERA. Notably, both the IJPM and the PMJ did not appear in the list suggesting that more empirical and rigorous research should be done by the PM academic community. Also evident is the difference of impact factor between the AMR and both CERA and JPIM. In short, the ranking of the representative Journal suggests that NPD has a slightly higher level of paradigm development than CE, whereas PM seems to lie far behind them.

In conclusion, research aimed at measuring and comparing CE, NPD, and PM maturity by using paradigm development assessment criteria emerged as a topic for the research agenda. The literature review and the empirical data, as well as the researcher's experience, suggest *prima facie* that NPD might have a higher level of paradigm development or maturity than CE and PM whereas there does not happen to be a difference between these two.

17. Is the expanding scope of CE, NPD, and PM a danger for the development of the subject?

Based on the Kuhnian concept of paradigm, CE, NPD, and PM might be tending to paradigm dissension rather than to paradigm consensus and consequently to less

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[12] The journal impact factor is the average number of times articles from the journal published in the past two years have been cited in the JCR (Journal Citation Report®) year.

technological certainty. The three appear to be growing by accretion and this phenomenon was criticised by Pfeffer in organisation studies:

> In the study of organizations, it is almost as if consensus is systematically avoided. Journal editors and reviewers seem to seek novelty, and there are great rewards for coining a new term. The various divisions of the Academy of Management give awards for formulating "new concepts" but not for studying or rejecting concepts that are already invented. (Pfeffer, 1998: 612)

Nonetheless, according to Kaghan and Phillips (1998) this is a reductionist or positivist vision and not necessarily the only one. There is also an irreductionist or constructivist perspective which assumes that knowledge is socially constructed and cannot be measured by consensus. Diversity of thought is not viewed as a constraint to paradigm development, but on the contrary, as an opportunity to grow in knowledge. This perspective is shared by those who rejoinder Pfeffer's critiques: Canella and Paetzold (1994); Van Maanen (1994); and Perrow (1994). Pfeffer's detractors maintain that there could not be so few theories explaining the complexities of the social world, and if there were, they would be evolving.

Feyerabend, in an overt critique "against the method" rejected Kuhn's philosophy of normal theory or paradigms, maintaining that there are no rules for scientific progress but "anything goes" (Feyerabend, 1980). To him, there is no such thing as epistemological consensus to achieve the category of scientific:

> Knowledge so conceived is not a series of self-consistent theories that converges towards an ideal view; it is not a gradual approach to the truth. It is rather an ever increasing ocean of mutually (and perhaps even inconmensurable) alternatives, each single theory, each fairy tale, each myth that is part of the collection forcing the others into greater articulation and all of them contributing via this process of competition, to the development of our consciousness. (Feyerabend, 1980: 30)

Lewis and Grimes (1999) explained the dispute in the following terms:

> Some fundamentalist lament the "anarchy" of paradigm proliferation, advocating a dominant paradigm to enhance the scholarly and political influence of organization theory (Pfeffer, Donaldson). Meanwhile, many postmodernists critique the hegemony of paradigms, calling for "anything goes" strategies more in tune with eclectic organizational discourses (Deetz, Feyerabend). (Lewis and Grimes, 1999: 672)

This dialectic (reductionst – irreductionst) may help to understand the claim for an irreductionst PM broader perspective vis-à-vis a reductionist PM execution perspective (Morris et al, 2006). The dispute might ultimately be a dispute for a postmodertnism diversity of knowledge versus a more fundamentalist view of a dominant paradigm.

The experience acquired during this research showed that it is fairly difficult to conduct research where there is a lack of consensus on the fundamental tenets in fields where (almost) everything goes. Nonetheless, the search for answers to essential questions in divergent fields certainly contributed to the development of researcher's own consciousness.

6.11 Limitations and evaluation of the emergent theory

> Authors of inductively generated theories have a particular responsibility for discussing limits of generalizability. (Whetten. 1989: 492)

It turns now on to evaluate to what extent the theory developed in this thesis is "good theory". The assessment is done in terms of four generally accepted criteria to evaluate qualitative research: generalizability, reliability, validity, and theory goodness. The richness (or weakness) of the data, the number and representative ness of the sample, and the link between data and emerging theory is evaluated.

In order to conduct the evaluation, the main limitations to conduct the enquiry should be first listed.

- The cases were selected "by convenience" (see Chapter 4). Strictly speaking, they were not selected but accepted as there were no more options. The main condition was that they were developing new products and applying CE, NPD, and PM.
- Few people from business or commercial departments were interviewed other than product managers in Company 1.
- Only four cases were developed instead of the initially planned six cases.
- Limited feedback from the companies' representatives who participated in the case studies. Only people from Company 1 agreed to conduct a follow-up workshop. Other companies received case reports and responded with a limited number of short e-mails.

- The performance of the companies was not evaluated nor correlated with the results.

Generalizability (external validity)

"Case studies, like experiments, are generalizable to theoretical propositions and not to population and universes" (Yin, 1994: 10). Every case study should not be considered as a statistical sample, but instead of that, by comparing where facts are similar or different (regardless of the frequency), properties of categories can be generated that increase the categories' generality and explanatory power (Glaser and Strauss, 1967: 30). Therefore, it is believed that the number of case studies (four) does not represent a threat to the generalizability of the concepts developed in this research.

The four cases were selected "by convenience" (Sanuders et al, 2000) (there were no other options) and therefore it is important to discuss to what extent this selection method might represent threats to generalizability. "The goal of theoretical sampling is to choose cases which are likely to replicate or extend the emergent theory" (Eisenhardt, 1989: 537). As Stuart et al (2002) recommended, cases should be chosen that differ from each other as widely as possible. Fortunately, the sample cases differed each other in several aspects (see the comparative table in Chapter 5), amongst others, size, product complexity, service/product type, and forces driven the development. Even the fact that Company 1 admitted not to have been applying CE was an opportunity to analyse likely extreme cases when compared with companies presumably pioneers on CE (Company 2). Additionally, multiple case study methods, as compared with single case study, can augment the research external validity (generalizability) (Voss et al, 2002: 202). Thus, the fact that the four cases were not selected but accepted does not seem to be a threat to generalizability on its own.

Glaser and Strauss (1967) also asserted that when the application of theoretical concepts developed within a group ("substantive theory") fit into different groups, then the explanatory power of those concepts is increased and the theory developed is thought to be more general ("formal theory"). Thus, the concepts and propositions developed here and stemming from empirical data are thought to be substantive theory applicable to companies whose characteristics are similar to those analysed during the case studies. Theory developed here can extend in application if it is proved fitting in another kind of companies (e.g. construction or software development).

An important question is to what extent the findings regarding the relationship between the product and the project manager (Issue 5) can be of general application if only product managers from Company 1 could be interviewed. Case study research relies on analytical generalization and therefore the limitation does not happen to represent a threat to the generalizability of the emergent concepts. Besides, secondary raw data (interviewees' comments on the business managers' role) confirmed the results obtained through primary data from Company 1 thereby increasing the generalizability of the concepts albeit representing a threat to validity as discussed later. Admittedly, if business or commercial managers from the other companies would have been interviewed, additional concepts and propositions could have been generated relating to the management of the project/product portfolio or the process to link the programs to business goals.

Reliability

"The underlying issue here is whether the process of the study is consistent, reasonably stable over time and across researchers and methods" (Miles and Huberman, 1994: 278). Reliability of inductive research rests on theoretical saturation (Glaser and Strauss, 1967), which implies that additional evidence does not add more explanatory power to the concept developed. The empirical results of this research are thought to be reliable since the emerging concepts were created from a systematic process of data coding and clustering aided by computational aids (QSR N6™ and Mind Manager™)(see details in Chapter 3). Concepts lacking enough raw data (evidence) to build consistent categories or properties were not considered.

The adherence to a careful, analytical, structured, and empirical procedure imparts confidence that the theory developed is reliable (Miles and Huberman, 1994; Eisenhardt, 1989). The information of the samples, the data collection procedures, and the framework from which to analyse data has been provided. The use of a detailed case study protocol and data base (in QSR N6™ software) improved the reliability of the study (Voss et al, 2002). Admittedly, the research was not devoid of intuition, imagination or creative laps, which are necessary elements to better theorizing (Mintzberg, 1979; Weick, 1989; and Lewis, 1999). However, in Mintzberg (1979: 585) words, that does not mean "fishing at random in the sea" and it is believed that those ingredients of *inspiration* (Weick, 1989) were administered in appropriate doses for not damaging the systematic nature of the research and therefore its reliability.

Validity (construct – internal)

"Here we arrive at the crunch question: truth value. Do the findings of the study make sense?" (Miles and Huberman, 1994). The study is based on empirical data gathered from 37 practitioners, people directly involved in the phenomena being researched where texts of the interviews were used as a primary data source. Documents describing the processes, the techniques and the players were analysed as a complementary data source. Among these documents were process manuals and diagrams, instructions, booklets, procedures and websites. Data from four different contexts were compared, juxtaposed or complemented. The variability of the cases, for instance between Company 1 and 2 or between Company 3 and 4, gave the opportunity to explore contingency factors and to confirm results through "theoretical replication" (Yin, 1994), i.e., "the emergence of contrary results but for predictable reasons" (Voss et al, 2002). Likewise, the close similarities between Companies 2 and 3 allowed one to predict and confirm similar results, which implies "literal replication" (Yin, 1994; Voss et al, 2002). The triangulation between texts, documents, and interviewees from different companies underpins the internal validity of this research.

Additionally, data from the literature were enfolded to ensure the sense making of the findings (Eisenhardt, 1989; Lewis, 1998). In some cases rival explanations were analysed (e.g., Wheelwright and Clark framework) to shape propositions and in some others similar findings were used and confirmatory results were drawn (e.g., the lack of effective tools for resource assignment and levelling). Thick and rich description of the corresponding case studies was attempted to enable a vicarious presence for the reader (Mintzberg, 1979: Miles and Huberman, 1994) and the level of uncertainty of results is now discussed (Miles and Huberman, 1994). These elements add internal validity to the study.

Particular findings, like those explaining the relationship between the product and the project management were generated by primary data (case study 1) but replications were supported by secondary data (indirect interviews) which could represent a threat to validity.

The main threat to internal validity is thought to be the lack of comprehensive feed-back from the informants so that the accuracy of results is at the stake (Miles and Huberman, 1994, Stuart et al, 2002). Companies' representatives received the case descriptions and only in Company 1 a follow-up session took place. In the other three cases the companies' representatives committed themselves to read the cases but no feed-back was obtained. At least the fact that they did not reply claiming inaccuracies may be a palliative to this threat. In these circumstances, multiple case studies increase the validity of results as the emergent theory is compared and replicated across the cases. Nonetheless, a more interactive discussion of the results with practitioners would have certainly increased the accuracy and enriched the description of the cases and additional evidence could probably have been collected (as happened in Company 1).

The performance of the companies to develop new products was not evaluated and therefore it could be reasonably questioned whether they were applying the "best practices". This study sought to investigate how experienced companies developed new products and not the influence of these practices upon performance because the purpose of this thesis was explanatory not confirmatory. It was therefore assumed that the level of experience of the managers participating in the study and the good market position of their firms increase the confidence in results obtained.

Theory goodness

The "true" test for validity in any type of research rests on developing good theory, theory that fits and works which means that "it is clearly applicable and relevant in a new situation" (Glaser and Strauss, 1967: 4). It is considered that the main concepts, propositions and relationships developed in this thesis were drawn from the data gathered in the field and therefore the theory developed will fit and work. Additionally, the results and contributions to knowledge are thought to be relevant as they can be operationalisable and applied in other similar settings (Whetten, 1989). Good theory from case study should result in new insights rather than simply validate existing theory (Sutton and Staw, 1989; Eisendardt, 1989). Although modest, new insights have emerged from this thesis and others confirmed previous results.

Admittedly, the evaluation presented above could be either cognitively or emotionally biased as it is doubtful that a researcher can escape from its own experience and emotions. Therefore the best and more neutral evaluation remains on the users of the theory: academics interested in developing further research or discussing the results; and practitioners appealed by the managerial implications of the findings.

Results of this work were presented in three research conferences, two faculty-peers presentations and one workshop with practitioners. This evidence reveals that the issues and findings are at least interesting and real which are two basic criteria to test conjectures in theory construction (Weick, 1989).

In general, the emerging theory of this research is considered to be reliable, valid (externally and internally) and relevant. In particular, however, the theory emerging from each research issue is considered to be at different quality levels. Therefore, every research issue was evaluated using the same criteria described above (generalizability, reliability, validity, and theory goodness) and results are shown in Table 6-8.

Table 6-8. Evaluation of the theory emerging from each research question.

Issue	Generalizability	Reliability	Validity	Theory goodness
1. What is nowadays the meaning of Concurrent Engineering for practitioners? For some practitioners CE is in general understood as parallel development, early involvement and multidisciplinary teams. They did not consider many techniques appearing in the literature. Most practitioners in two companies did not recognise the term.	Medium	Med	Medium	Validation
2. How can the meaning of concurrency or concurrent be explained in order to avoid confusions with terms like parallel, simultaneous or teamwork? The new concept of Meta-concurrency and convergence was empirically developed to clarify this subject.	High	High	High	Explanation
3. How can CE be better explained? Meta-CE is an enhanced approach to engineer products through the application of multidisciplinary teams working in parallel and converging on data and knowledge.	Medium	High	High	Explanation
4. What is the practitioners' experience and perception about sequential and parallel development and the risk of rework? For some practitioners the parallel development was less risky as they were using techniques to increase the level of communication.	Med	Medium	Medium	Validation
5. Are the design structure matrices (DSM) used by engineering groups and not by project managers? The evidence confirmed this assumption and the reason may be that it is a tool for process improvement.	Medium	Low	Low	Validation
6. How do managers deal with the problem of resource imbalance in a CE-type environment where overlapping is constantly applied in order to shorten projects lead-time? They still struggle with the problem; better and cheaper tools should be developed.	High	High	Medium	Validation
7. What is the PM scope of application in developing new products? The Pm execution perspective seems to be applicable within a broader NPD process. The PM broader perspective happens to be a substitute of the NPD.	High	High	High	Explanation

Evaluation criteria:

- Generalizability (low – medium – high): Data from different cases is underpinning the concepts; the findings are consistent with experience or confirm results appearing in the literature but applied in different contexts; the outcome is generic enough to be applied in different settings.
- Reliability (low – medium - high): The research questions are clear; concepts are theoretically saturated; adherence to the research method; the use of a case study protocol; replicable in other settings.
- Validity (low-medium-high): Type of data used (empirical, from the literature or from researcher's experience); data source (primary - secondary); empirical data triangulation; literature enfolded; analysis of rival explanations; "thick" case description; replication logic; feed-back from informants.
- Theory goodness (validation – explanation – new insights): Relevant; interesting; fit with data; operationalizable and applicable to new situations, it raises debates.

Table 6-8. Evaluation of the theory emerging from each research question.

Issue	Generalizability	Reliability	Validity	Theory goodness
8. What is the relationship between the product manager and the project/program manager during the development of new products? A dynamic and dual relationship was taking place. Product managers had a higher position in two companies. The likely reasons are explained.	Medium	High	Low	New Insights
9. How can it be explained that CE, NPD, and PM classification systems subsume each other? Subsuming one approach into the other at an abstract level might be confusing. Rather specific tools should be grouped around methodologies or tool-kits for practitioners regardless of names or brands.	High	Low	Low	Explanation
10. What is the cause-effect relationship, if any, between CE, NPD, and PM? Pm (execution perspective) and CE basic principles benefit to each other. NPD or PM and CE specialised techniques do not show a direct cause-effect relationship. A recommended cause-effect model and a sequence of implementation are proposed.	Medium	Low	Low	New insights
11. When should the project manager and the project team be engaged and disengaged during the process to develop new products? Process models were obtained explaining the engagement of product managers, program and project managers, and chief engineers or specialists	Low	High	Low	New insights
12. Is the APQP a suitable and complete model for developing new products because it combines CE, NPD, and PM elements? Apparently yes, providing the necessary mechanisms to align business goals to projects.	Medium	High	Medium	New insights
13. How can the relationship between CE, NPD, and PM be explained through interlinked process models? Through aligning schemas relating PM and NPD processes. Business processes were the umbrella processes. CE can difficulty be depicted as a process.	Medium	High	High	Explanation

Evaluation criteria:

- Generalizability (low – medium – high): Data from different cases is underpinning the concepts; the findings are consistent with experience or confirm results appearing in the literature but applied in different contexts; the outcome is generic enough to be applied in different settings.
- Reliability (low – medium - high): The research questions are clear; concepts are theoretically saturated; adherence to the research method; the use of a case study protocol; replicable in other settings.
- Validity (low-medium-high): Type of data used (empirical, from the literature or from researcher's experience); data source (primary - secondary); empirical data triangulation; literature enfolded; analysis of rival explanations; "thick" case description; replication logic; feed-back from informants.
- Theory goodness (validation – explanation – new insights): Relevant; interesting; fit with data; operationalizable and applicable to new situations, it raises debates.

Table 6-8. Evaluation of the theory emerging from each research question.

Issue	Generalizability	Reliability	Validity	Theory goodness
14. How can CE, NPD, and PM be essentially conceptualized so that they can be comparable? PM and NPD can be seen as processes within an overall CE status of excellence in engineering.	High	Medium	Medium	Explanation
15. What is the difference in purpose, if any, between CE, NPD, and PM? NPD seems to be know-what whereas CE may be basically know-how. PM can be both know-what and know-how.	High	Medium	Medium	Explanation
16. Do CE, NPD and PM have different levels of maturity? NPD seems to have greater level of maturity than CE and PM and a difference between CE and PM was not observed.	High	Medium	Low	New insights
17. Is the expanding scope of CE, NPD, and PM a danger for the development of the subject? From a reductionist perspective yes, from an irreductionist perspective no, the debate should go on.	High	Low	Low	Explanation

Evaluation criteria:

- Generalizability (low – medium – high): Data from different cases is underpinning the concepts; the findings are consistent with experience or confirm results appearing in the literature but applied in different contexts; the outcome is generic enough to be applied in different settings.
- Reliability (low – medium - high): The research questions are clear; concepts are theoretically saturated; adherence to the research method; the use of a case study protocol; replicable in other settings.
- Validity (low-medium-high): Type of data used (empirical, from the literature or from researcher's experience); data source (primary - secondary); empirical data triangulation; literature enfolded; analysis of rival explanations; "thick" case description; replication logic; feed-back from informants.
- Theory goodness (validation – explanation – new insights): Relevant; interesting; fit with data; operationalizable and applicable to new situations, it raises debates.

Chapter 7 Conclusions and contributions to knowledge

In this concluding chapter, a general explanation about the relationship between CE, NPD, and PM is summarized. Afterwards, the contributions to knowledge are presented in two parts: first, the main insights for practitioners to improve their product development practice; second, the concepts, propositions, relationships and questions that may nurture the research agenda. A brief summary of the theoretical background and findings is first dwelled upon.

7.1 Summary of the theoretical background

The building of strong in-house capabilities to develop new products is central to companies' strategies for survival. Developing innovative and high-quality products at competitive prices is a feat that practitioners face through the implementation of the so-called 'best practices'. Underlying these practices are theories developed by researchers from different academic communities.

Academic communities have studied product development under different perspectives, for instance as a technological challenge, as a commercial problem, as an organisational concern, or as a complex project to be managed. The problem is firstly, that theories developed under each perspective lack of cross-references to the others, thereby inhibiting the possibilities of building more comprehensive theories. Secondly, the literature explaining the relationship between these different perspectives from a neutral or metaperspective is scarce. Concurrent Engineering (CE), New Product Development (NPD), and Project Management (PM) happen to experiment this poor complementarity and scarcity.

Both formal and informal interviews with many experts (academics and practitioners) from the different professional communities confirmed the tacit separation among CE, NPD, and PM. These experts seemed to have different "ways of seeing" product development. Moreover, they showed a tendency to praise the superiority of their respective approaches – that which they have studied or worked with - and to minimise *the other* approach.

Therefore, multi-disciplinary research aimed at building bridges between different academic and professional communities of practice seemed to be justified. The research sought to understand the relationship between CE, NPD, and PM, not as an end in itself, but as a means to improve product development. Hence, the main purpose of this dissertation was:

To develop an exploratory study aimed at understanding the relationship between Concurrent Engineering, New Product Development, and Project Management.

Three general research questions were expected to be answered in this investigation:

(a) Do CE, NPD, and PM emphasize essentially the same aspects (practice and purpose), or are they distinctly different?

(b) Are CE, NPD, and PM competing or complementary?

(c) Is one a component or precursor of the other?

The lack of answers, the contradictions, and the confusions in the extant literature raised research issues and question which constituted the theoretical framework of this thesis (Chapter 2).

Two different perspectives of PM were found while reviewing the literature: The PM execution perspective (Pm) and the PM broader perspective (PM). The Pm execution perspective, presumably exemplified by the PMBOK of the PMI in USA (PMBOK-PMI, 2000) was orientated toward the execution of the project, that is, the planning, execution and closure. The main success criteria under this perspective were the time, cost, and product performance. The PM broader perspective, exemplified by the PMBOK of the APM in UK (PMBOK-APM, 2000) included the strategic orientation of the project and additional success criteria, such as the technology of the product, politics, environmental and safety aspects. Thus, it was interesting to investigate the role that each perspective played in product development.

Exploratory research was developed through case studies in order to understand how practitioners developed new products and manage the relationship between CE, NPD, and PM. The process to develop the new product was the unit of analysis. Interviews with 37 managers and specialists were conducted. Additionally, documents were analysed and compared with the data gathered from the interviews. Principles of grounded theory (constant comparison between theory and data) and qualitative analysis were the main inductive methods employed to analyse the corresponding data.

Four companies were surveyed in order to gain an insight into how they developed new products and applied CE, NPD, and PM. The main findings are presented in Chapter 4. Three companies manufactured products for the aerospace and automotive sectors; the other company was a service-type company within the telecommunications sector. Sizes, the nature of the market, the complexity of the product and production volume were the most significant differences; these were analysed in Chapter 5. The differences and the similarities between the companies enabled data analysis from different points of view thereby helping to explain and discuss the research issues and questions (Chapter 6).

7.2 Conclusions

The results of this study suggest that CE, NPD, and PM are relatively different in practice and purpose. However, as they are applied to improve the development of new products and because their scope has been increasingly growing, they interact so closely that it has not been easy to distinguish each one's emphasis. The lack of a clear distinction might be converting them into competing practices as has been empirically observed.

On the other hand, however, the empirical identification of CE, NPD, and PM's conceptual core suggests that they can be complementary and therefore managers can improve their product development practices with lower levels of investments by taking advantage from their particular benefits and specific purposes (summarized in Table 6-6)

CE happens to be a multitude of approaches, rather than a single approach, aimed at improving product quality. It has been conceived in this thesis as a *status* to be reached in engineering products. Unfortunately, the field research confirmed the lack of consensus regarding a working definition of CE and the corresponding danger for the development of the subject. This study contends for a re-assessment of the CE fundamentals and the formulation of clearer definitions from which the layman can follow a path towards a status of excellence in engineering. To this end, a novel definition of CE is proposed which is considered simpler but emphasizing the most important CE characteristics found in the field, namely, work-in-team, parallel development, and convergence on data and knowledge. The systematic application of these distinctive CE principles will help companies to improve the quality of their products, to decrease the levels of rework, and to shorten the lead-time. Although not explicitly mentioned by practitioners in the case studies, it is implicit that costs are cut by reducing the levels of rework (for instance in materials or labor).

NPD was seen primarily as a business process to develop new products which emphasizes the need for filtering products through a portfolio and for periodically reviewing the convenience of keeping products within the portfolio through business gateways or milestones. NPD helps managers to define what products need to be developed in order to meet the company's mission; it can be understood as *know-what.* In the field, it was understood as a high-level business process which necessitated a complementing approach to define how the selected products would be developed and delivered. This approach was the Pm execution perspective which might then be understood as *know-how.* CE was also considered as *know-how*, however, whereas Pm was positioned and applied in the four companies, CE was not so well positioned and it was even ignored by some practitioners.

Both CE and NPD contained elements to specifically targeting customer needs. This particular focus was neither emphasized by program and project managers in the field nor addressed in the PM literature. For instance, studies showing the applications and benefits of QFD (Quality Function Deployment), a technique specifically designed to transform customers needs into design and production parameters (Hartley, 1992), have been practically absent in the PM literature. Therefore, based on the study of two cognate disciplines (CE and NPD) both in theory and practice, it is recommended that more research should be done by the PM community about the application of tools and techniques specifically targeting customer needs, like QFD.

The two different perspectives of PM were observed in the field. However, while the Pm execution perspective was uniformly understood and applied in the four companies, the PM broader perspective was perceived and applied differently. As has been mentioned, the Pm execution perspective happens to be a *know-how* in product development. As characterized in the literature, and confirmed by practitioners in one company, it can be the approach to develop the products *right,* while NPD can be the approach to develop the *right* products. Program and project managers may improve their Pm practices by applying the CE principles. CE's more advanced techniques were found to be part of the designers' domain rather than program and project managers'.

The PM broader perspective was also understood as a business related process to link business strategies to programs or projects (as NPD). In this sense the PM broader perspective can also be considered as *know-what.* This particular appreciation was observed in companies 2 and 3. However, practitioners from the other companies 1 and 4 did not consider this broader view of PM but only the Pm execution one. This suggests that the PM broader perspective suffers from a lack of positioning in different industry sectors. It is speculated that *minor* programs or projects (low levels of investments, relatively simpler, less innovative) are managed through a Pm execution perspective together with different mechanisms to link programs and projects to business goals. Similarly, it is speculated that the higher the level of project innovation or uniqueness the greater the need for applying the PM broader perspective, whereas more repetitive projects requires Pm execution techniques complemented with process management techniques as it has been already proposed in the literature. The application of Design Structure Matrices to improving the design process, as observed in one company, represents a good example of this complementarity.

CE, NPD, and PM cannot be seen as a component one of the other. They have so many methods, tools and techniques that trying to subsume one into another may lead to confusions in practice. Classification systems appearing in the literature that include one into another might serve best as illustrative purposes to indicate the complex nature of product development.

The field research and the analysis of the literature unveiled cause-effect relationships that through further research may be confirmed in order to guide managers in the sequence of implementation or to improve their actual practices. Pm happens to be the approach that needs to be first in place in order to ensure that teams have the necessary skills to carry out the programs and projects or to "get things done". Then, CE fundamental tenets could be applied so that the teams and the project manager can improve their results (better quality, less rework, less time). Pm might then evolve to a PM broader perspective or an NPD approach for ensuring that project goals are linked to business goals. Finally, CE more complex techniques may be implemented somehow independently of the NPD approach but necessarily after the teams preparation on Pm and CE fundamentals. These suggestions were basically drawn from the chronological order in which the approaches were implemented in the four companies alongside practitioners' opinion and CE, NPD, and PM main purposes.

"A paradigm is what the members of a scientific community share, *and*, conversely, a scientific community consists of men who share a paradigm" (Kuhn, 1970: 176). CE, NPD, and PM are the *credo* of different professional communities. Different concepts, positions, way of doing things, literary sources, professional backgrounds and the like were observed during this comparative research. Particularly evident was the lack of cross references between the different studies and journals representing the different academic communities. It is believed that this tacit separation retards the development of the subjects as discoveries made in one field are not seriously considered in the other as has been exemplified in this thesis. Likewise, professionals in the field showed a tendency to think and act according to their organisational functions, whether NPD or commercial-related, CE or technical-related or PM-related. However, unlike academics, practitioners do not ignore others' disciplines because, after all, product development is a multidisciplinary task. They apply eclectic solutions as the aligning schemas described in Ch. 5 or even duplicate efforts, as expressed by a program manager "better in there twice than nothing". Therefore, there is a need for building bridges between cognate disciplines in order to improve product development practices and this work is thought to contribute in this effort.

The CE, NPD, and PM academic communities have developed definitions, concepts, techniques, classifications, goals, and metrics. They have preferred research methods and journals and attend to their own particular conferences and symposia. They were born in different times and are increasingly growing in scope. All these characteristics and the fact that they strive for the application of more rigorous or scientific research methods suggest that these communities pretend (consciously or unconsciously) to become scientific. This intent can be explored in future research by using the Kuhnian concept of paradigm development. Based on the experience gained in this research it is speculated that NPD might have a higher level of paradigm development than CE and PM. The exploratory study also questioned the tendency to grow in scope as, from a reductionist point of view, it may represent a danger for the development of the subjects. However, from an irreductionist point of view it is recognised that each of these subjects is socially constructed and therefore they can hardly be hemmed in by a limited quantity of theoretical principles.

7.3 Contributions to knowledge

The main contribution of this study is thought to be the explanation and clarification of otherwise confusing, contradictory or still non-refined theories. Practitioners may benefit from new concepts, models, and relationships that clarify the practice of product development. Although not the original goal, the research brought about reflections regarding the very nature and ultimate goals of the CE, NPD, and PM approaches that might raise the interest for further ontological or epistemological debates.

7.3.1 Contributions for practitioners

This dissertation may help to improve best practices in product development through the following contributions:

- An empirically developed framework that clarifies and sharpens the difference between the roles of program and project managers and presents contingent conditions to apply PgM. This clarification will enable executives to differentiate and consequently reinforce the corresponding roles, thereby optimising efforts and resources.

- Graphical constructs in the form of aligning schemas that will help to harmonise the different processes carried out in developing new products. These aligning schemas reflect the need for an umbrella business-orientated process and multidisciplinary check-lists to review performance in every strategic gate or milestone along the process.

- Process patterns along the product life cycle showing the start and ending point of business-related, PM-related, and engineering-related processes. These patterns may guide managers to take decisions around the engagement and disengagement of product development staff along the product life cycle, i.e., program and project managers, product managers, and engineering specialists.

- Modifications to the known funnel-model proposed by Wheelwright and Clark (1992). The modified model, called multi-level, clarifies the levels of analysis in which long, medium and short term processes should be observe.

- A new, empirically developed framework which explains more clearly what CE is and its main elements. The framework proposes the concept of *meta-concurrency* instead of simply *concurrency* to avoid the existing confusions in the literature. The new concept hinges on three basic tenets, convergence, work-in-team, and parallel working, from which companies can configure the most suitable techniques to continuously improve their engineering practices. This is particularly valuable since current research, as presented by CE communities, "does not yet give many handles for supporting companies in deciding on suitable configurations" (Wognum et al, 2003: 6).

- Empirical evidence stressing the need for training program and project managers in CE. The case studies confirmed their significant role in the successful application of CE but, regrettably, no such training was formally given. To facilitate the training, the new model of CE offers a simplified, though complete framework. This training should include the use of CE tools to optimise activity sequencing, like the application of the DSM technique, customer focus techniques like QFD, and how to combine them with traditional PM tools. The training should make program and project managers realise that they can greatly contribute to the success of CE by applying its fundamentals: convergence (e.g., by facilitating communication), parallel development (e.g., by promoting the use of CE and PM scheduling tools), and work-in-team (e.g., by creating a climate of trust and collaboration).

- Empirical evidence showing that CE main benefits are quality and less rework and not always shorter lead-times and cost reductions as purported in the literature. This new perception of CE becomes an invitation to managers and executives to more firmly support this valuable approach.

- An empirically-based explanation of the relationship between product and project managers in a specific context (case study 1). Unlike other literary sources, the evidence showed that both roles interact dynamically along the project life cycle in order to effectively co-ordinate the development of new products. This combination emerges as an alternative to the heavy-weight product or program managers, resources with a strong profile who are not always available. Marketing forces driving the development seems to be a condition that favours this dual assignment.

- A proposition to apply the APQP standard guide as an easy-to-use approach to product development that combines CE, NPD, and PM elements. This guide may suit the needs of small and medium enterprises (SMEs), which do not always have supporting staff for developing home-made methodologies. However, practitioners should "patch" the APQP by providing mechanisms to ensure that the projects being developed are aligned with business goals and strategies; mechanisms that seem to be absent in the globally acknowledged quality standard guide.

- Insights on the relationship between product complexity and the need for co-location. Confirmatory results indicate that the higher the product complexity, the higher the need for co-location and, the lower the product complexity the lower the need for collocated teams.

7.3.2 Contributions to the research agenda

> A case study does not settle issues very often, its main utility is in raising them. (Gerwin, 1981: 70).

Both the exploratory nature of this research and the case study methodology, as the means to conduct the inquiry, brought about results that need to be proven, refuted or discussed. Therefore, the concepts, propositions, and frameworks developed here should be tested empirically, e.g., via surveys or by implementing them in the field. Additionally, the limitations of the research indicate topics for further research. Therefore, to nurture the research agenda, this thesis brings about the following contributions:

- A multidisciplinary research which integrates a rich source of bibliographical references on three different areas. This outcome is aimed at building bridges between three professional communities (CE, NPD, PM) which lack cross-references. This is particularly valuable given the sheer volume of research material being produced, "meaning that it is very difficult for anyone to keep fully abreast of developments in more than one area". (Easterby-Smith et al, 1998:5)

- A confirmation that PM might be regarded in its broader perspective, that is beyond execution (planning-excuction-closure), in order to obtain better project results. However, the PM broader perspective was not as well-positioned as the Pm execution perspective. Differences in industry sector and language are thought to be the main reasons to understand why broader approaches like the Management of Projects or Program Management are neither commonly understood nor well-positioned.

- The development of an original and structured concept of *meta-concurrency*. Unlike the perhaps excessive conceptual properties of actual definitions, the concept is based on three fundamental tenets only: convergence, work-in-team, and parallel development. Each of these elements has conceptual categories, properties, and dimensions. Some of them have already been researched but others are still to be empirically proven. Furthermore, the concepts helps to build a new concept of CE that is thought to be simpler and more logically coherent than the classic CE definition coined by Winner et al (1988) and simpler than the definition of Cletus (1992). Finally, the concept of *meta-concurrency* will support research aimed at exploring more extended approaches, like concurrent product development, concurrent product introduction, or concurrent life cycle.

- A cause-effect model showing the relationship between CE, NPD, and PM as well as a likely order of implementation. This empirically induced model is worth to be tested and confirmed in practice.

- An introspective reflection regarding the very nature (ontology) and goals (teleology) of CE, NPD, and PM and their underlying professional communities. The analysis suggests NPD might be more mature than CE and PM if maturity is measured by the level of paradigm development. This suggestion might produce reactions amongst researchers since it is based on paradigm consensus as opposed to "socially constructed" knowledge or paradigm diversity.

- A call for further research addressing the relationship between project management and process management.

- The limitations of the research highlighted the need for investigating the role of business, marketing, and sales people in product development. A better knowledge about their activities and responsibilities will be useful to complement the results of this thesis, which primarily involved developers (project managers and specialists).

- An appeal to increase the generalizability of the concepts. It would be interesting to develop similar research in other contexts, for example with software developers, financial institutions, or companies offering courses and seminars.

- A call for proposing solutions to the problem of resource imbalance in a CE type environment. Even though three professional communities (at least) have investigated and developed tools to the timely assignment and control of resources, the findings evidenced a shortage of simpler and less expensive but effective tools to solve this problem.

Appendices

Appendix A. Preliminary conceptual framework

The following conceptual framework was developed during the literature survey to understand the differences, similarities and interfaces between CE, NPD, and PM. The framework contained propositions, premises and a rough conceptual schema. Although it was not used for pattern matching, it was useful to focus the research process and to elaborate the case study protocol. Interestingly, the final empirical results showed that some concepts resulted as predicted here. Following, the framework as it was written during the literature survey.

Conceptual model of NPD process and projects

The following conceptual model is aimed not only at understanding the differences, similarities and interfaces between PM, NPD process and CE, but also to formulate strategies to improve the NPD performance based on the complementarity and synergy of the three knowledge areas.

Differentiation concepts and its premises

The conceptual model is conceived by proposing two differentiation concepts:

a) Project Management does not have the same meaning as the Management of the Project.

b) Although interrelated, project does not have the same meaning as process.

The first concept has been hypothesised, explained and grounded by Morris. It is a relatively new proposal based on a broader spectrum of project success factors than those traditionally indicated within a Pm execution perspective (time, cost, quality).

In order to explain and substantiate the second concept (b), one can propose the following analogy: imagine the event of travelling from one city to another by car, aided by a map on which the path is outlined. Therefore, one can state that:

- The *process* is the path.
- The project is the *event of coursing* that path, i.e., is the *travel* itself.

Based on this, one can posit the following premises regarding the differences between project and process:

- Premise 1. A process (like a path) can be mapped, analysed, simulated, and even re-engineered, although not managed (no one can manage a map).
- Premise 2. The project (like the travel) must be executed, ergo, it can be managed.

From the previous premises, the term process management and its derived term process manager does not exist within this conceptual model (process analyst could be the corresponding role). The analogy of travel can also help one to understand another related term. During travelling, one can send and receive data about the conditions of the travel and about the conditions of the city to reach (product).

- Analogously, one can deduce that, during the project, one can send and receive data about the conditions of the project (project control) and about the characteristics of the product (product data management).

Hence, the following premises are proposed to better understand and improve the NP performance:

- Premise 3. Concurrent Engineering relates the analysis and improvement of the engineering process.
- Premise 4. Project Management relates the execution of a project, in this case, the engineering project.
- Premise 5. Both, PM and CE are concerned with the management of the product.

In analyzing the premises 3 and 4 against findings in the literature and interviews, it can be deduced that both knowledge areas, PM and CE, have mutually "invaded" their spheres of action. PM has explored the analysis and improvement of processes, whilst CE has explored the management of the project.

Premise 5 coincides in general with the actual CE and PM practice: quality control, specifications, performance, customer driven, and so on In this case it would be fruitful to complement the corresponding tools and approaches.

Despite the fact that many CE academics and researchers have idealised the extent of CE comprising the whole product life cycle, the vast majority of research and applications of the CE community has been done within the engineering (i.e., design engineering) and the manufacturing of the product.

In that circumstance, one could intuitively ask who has addressed in deep the study of whole product life cycle. An answer consistent with the present order of ideas can be given by applying the travel analogy: imagine that one has to travel to a city (final destination) passing through several towns (intermediate destinations). In this case, the following premises are proposed regarding NPD and the Management of the Project:

- Premise 6. The New Product Development *process* relates the analysis and improvement of the whole process, from idea to product recycling.
- Premise 7. The Management of the NPD (MNPD) *project* relates the planning and execution of all the project stages through the product life cycle, taken as a whole.
- Premise 8. Both, NPD and the MNPD are concerned with the management of the product.

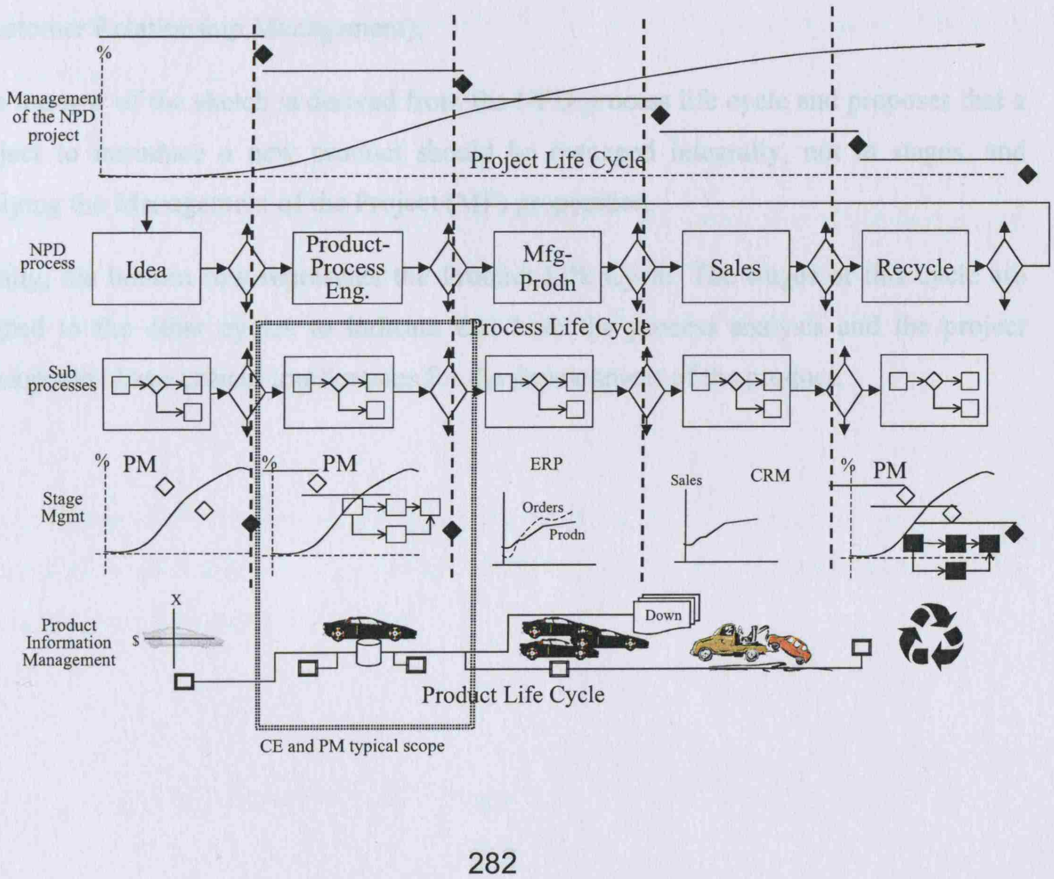
Comparing premise number 6 with the results of the current literature survey, one might say that NPD traditionally has studied the analysis and improvement of the whole process mainly under the organisational paradigm, in which each stage is executed by different departments in an organisation.

Taking premise number 7, one has few elements to compare because no references have been found regarding the Management of the Projects within the NPD literature or industrial practice. For the vast majority of the research and application, the project management perspective has ruled (narrow scope). However, NPD authors propose measures for success and failures criteria that are akin to those discovered by the management of the projects (MP) concept, yet applied in project-type organisations only. Therefore, it should be interesting to compare those success criteria found within MP and NPD. If they are similar, how do they complement each other? And how MP can help NPD?

It should be noted though, that NPD research and applications have not disregarded the improvements on execution of NPD projects. Heavyweight project managers, product managers, project sponsors, are terms that relates to (and justifies) the holistic management of the NPD. Premise 7 is then a taxonomic proposal to address the strategic execution of the project related to the whole process. This is the project perspective postulated by Tatikonda and Rosenthal (2000) in which the development of an individual product can be viewed as the organisational process of managing a project.

Premise 8 coincides with the actual practice, as the case of PM and CE (premise 5), with the sole distinction that PM and CE are related to an intermediate product (the engineering or the prototype) and NPD and MNPDP are concerned with the final product.

The following figure illustrates the conceptual model already explained.



The model is explained as follows:

The departure point is the second row from top, showing a generic process life cycle extending from the original idea to recycle and a loop to go back to the starting point. This process is the New Product Development (NPD) process

The whole NPD process can be broken down into sub-processes. This deployment has been represented below the NPD process, i.e., the third row from top.

Both the whole NPD process and the corresponding sub-processes can be analysed and improved, as has been proposed by CE and NPD scholars. Indeed, the stereotypical scope of CE since its origins has been within engineering.

The fourth row from the top represents the corresponding management stage of each sub-process. Projects to develop new ideas, to achieve the engineering, and to recycle certain products can be managed with PM tools and techniques, although the stereotypically narrow view of PM application remains on engineering.

Manufacturing or production stages, as well as sales campaigns, are typically managed through other kinds of tools, like ERP's (Enterprise Resource Planning), and CRM's (Customer Relationship Management).

The top row of the sketch is derived from the NPD process life cycle and proposes that a project to introduce a new product should be managed integrally, not in stages, and applying the Management of the Project (MP) proposition.

Finally, the bottom row represents the Product Life Cycle. The stages of this cycle are aligned to the other cycles to indicate that both the process analysis and the project management have critical implications for the development of the product.

Appendix B. Access letter

(Date)

(Company data)

To Whom It May Concern:

I am currently researching about the relationship between Project Management (PM) , New Product Development and Concurrent Engineering initiatives to improve the development of new products. The research is part of a PhD Programme at University College London (UCL).

In order to learn from your experiences, I would like to ask permission to develop a case study in your company. It will consist mainly of interviews and document review and it is expected to take between two or three weeks, depending on the availability of persons and documents.

Your company will be benefited with both, the results of the individual case study and the comparative study once all case studies have been made. All the information will be treated with the utmost confidentiality.

Attached you will find a summary of the proposal/requirements. If you require any further information, please do not hesitate to get in touch.

Yours truly,

Adan Lopez Miranda

(Contact data)

Case Study Proposal

Research problem: Different well established practices have been applied to enhance the development of new products, between them, Project Management (PM), New Product Development (NPD) methodologies, and Concurrent Engineering. However managers seem to confront the decision of which techniques are more convenient to implement, regardless of its potential complementarity.

Research goal: To explore and describe how successful companies have managed the relationship between Project Management, Concurrent Engineering, and New Product Development methodologies to improve the new product development.

Research methodology: Case study will be performed in companies that have implemented a systematic methodology to develop new products. The case study will be based on interviews and document review and it is expected to take between two and three weeks, depending on the availability of the information.

Benefits for the companies:

1) The interviews and document review will give the managers and people participating in the development of new products the opportunity to reflect upon their own process thereby increasing the possibilities to improve it.

2) The individual report of the case study, written in executive form (non-academic) will render a synthetic document showing the current picture of the process being analysed.

3) The final comparative report (written in executive form) will give the company the possibility to evaluate its practices against the reported best practices.

Research team: (Researcher and academic supervisor's names and brief professional curricula).

Information required: Interviews with different persons involved in the implementation and operation of the new product development process. Expected time in each individual interview is between one and two hours. Document review, like the in-place methodology to develop new products, and archives regarding the implementation process, including feasibility studies, job descriptions, organisational charts, memos, minutes, plans, and so on.

Facilities: The interviews and document review will take place in the company facilities. It is expected that the company could grant a working place for the researcher during the time the case study is developed. The analysis of the data will be performed in the University research centre, but copies of documents can be required for further evaluation, hence access to a photocopier will facilitate the research.

Appendix C. Case study protocol

Section A. Overview

A.1 Purpose

This protocol is issued to guide the investigator in carrying out the case study. It contains the base line instrument, the procedure and the criteria for using the instrument. A working Instrument will be issued for each case study.

A.2 Background

Research goal: To build an original framework describing and explaining the relationship between PM, NPD, CE and MoP through recursively using qualitative data drawn from case study and theory.

Research process:

a) Preliminary constructs

b) Development of the case study

c) Data Analysis

d) Refining the construct

e) Development of the next case study

f) Data Analysis

g) Refining the construct

h) Iterating until no substantive additional information is gained

Case study goal: To develop a detailed description and explanation about the management of NPD, CE, and PM to improve the new product development performance.

The settings and the unit of analysis:

- The settings will be production units that develop new products and that have incorporated at leas two of the initiatives under research.
- The case or unit of analysis is the implementation, operation and improvement process of CE, NPD and/or PM processes to develop new products

Case study strategy: Inductive, being attentive to what, how and why companies think as they actually do. I do not know more than the practitioners in their field, my contribution will be to generate descriptions that provide them with a guide.

Case study process:

a) Initial interview with the person assigned by the company to co-ordinate the case study. The goal is to review the case study process.

b) Document review, beginning with the in-place methodology to develop new products.

c) Interviews with key participants on the implementation and operation of initiatives to develop new products.

d) Further document review and interviews, if needed.

e) Data analysis (in the researcher's University facilities)

f) Issue of individual report.

A.3 Organisation of this protocol

- An overview of the case study project
- Field procedures (credentials and access to the case study "sites", general sources of information, and procedural reminders)

- Case study questions (the specific questions that the case study investigator must keep in mind when collecting data, check-lists and potential sources of information for answering each question).
- A guide for the case study report (outline, format for the narrative, and specification of any bibliographical information and other documentation)

Note: The first three sections will be part of the Instrument and will be tailored to the company to be visited.

Section B. Field procedures

B.1 Preparing the visit

Preparing preliminary information

a) Date and time

b) Addresses and persons to visit, how to arrive

c) Agenda

d) Reviewing the company website

Verification of access procedures

a) Access granted document

Special documents

b) The case study proposal

c) The case study protocol

d) The instrument

Other aids

a) Checking the laptop, AC adapter, files, Internet card and cable.

b) White paper, paper clips, post-its

c) Folders to carry copies

d) Tape recorder, cassettes and batteries

B.2. Initial field visit

Agenda

- Personal presentation
- Case study proposal
- Getting official acceptance or rejection
- Preparing the working plan

Information required

- Personal presentation with the person responsible to co-ordinate the case study.
- Asking for his business card
- Asking for a source of information about Company's commercial and public financial information.
- Asking for accommodation and meals support

Section C. Questions

C.1 Framework and strategies

Framework for case study design and data collection (From Yin, 1994, page 72).

Data collection source (About an organisation)

Design	From an individual	From an organisation	**Study conclusions**
About an individual (NOT APPLICABLE)	Individual behaviour Individual attitudes Individual perceptions (NOT APPLICABLE)	Archival records (NOT APPLICABLE)	If case study is an individual (NOT APPLICABLE)
About an organisation	How organisation works Why organisation works	Personnel policies Organisation outcomes	If case study is an organisation

- Three sources of evidence: documentation and archival records, interviews, and direct observations.
- The questions are designed to ask *me* (the investigator), not the interviewees.
- Ask for specific examples, practitioners prefer to be specific rather than speaking of abstractions.

Question type, sources of data, and sampling

Question Type

- Question in bold and with (✓) means general question.
- Question in regular text, means second level of detail
- Question without (✓) means that it represents a question of the pre-existent theoretical framework
- Questions marked with (**G**) are general questions whose answers serve as a context

Informants

Informant	Abreviation
Plan Manager. Person whom functional managers report	Mgr
Functional Manager. Engineering Mgr., Marketing Mgr., and so on.	FMgr
Program Manager. Director of project/product managers	PrMgr
Project or Product Manager	PM
Specialist	Sp
Implementator. Person responsible for implementing the new initiative	Imp
Implementator assistant	ImpAss
Product sponsor. Manager or director finally responsible for the launch of new product	Spo
Project assistant. Project scheduler and controller	PmAss
Process analyst. Person in charge of improving the process	PrAnal
Internal or external consultant. Person advising the implementation, operation and improvements	Cons

Documents

Document	Abreviation
Company commercial catalogues	Cat
The in-place methodology to develop new products	Meth
Organisational charts	OCh
Job Descriptions	JobD
Feasibility studies	FeaS
Cost documents, budgets and expense reports	CostD
Memos and minutes	Mem, Min
Implementation and Project Plans (schedules, goals, progress reports)	ImPlan, PrPplan
Performance measures: lead-times, profits per product, investments in product introduction, investments in NPD improvements, rework	PerfM
Papers in journals	Papers
Publications like company news or articles in commercial magazines, newspapers or the company website.	Public

Sampling

Sampling	Abreviation
Not indicated. Means that there is only one person or source, or, all sources or persons will be reviewed/interviewed	
As many as I can. Depends on the availability of persons, documents and my time. At least one sample is expected.	Many
At least one each speciality	AL1
As required. Depending on the previous findings	As Req

C.2 Questions on the Implementation

✓Basically of what did the implemented NPD/CE/PM initiative consist?

✓What were the main reasons to implement a systematic NPD/CE/PM initiative or methodology?

✓Who was responsible for the decision to implement and for the implementation itself?

✓How was it to be implemented?

✓What were the problems implementing it?

✓What were the benefits after implementation?

✓Were they measured? How?

✓What were the problems remaining after the implementation?

✓What is or has been the amount of investment to implement the initiative? On what issues? (training, equipment, and so on.)

✓Is your methodology a standard product of any consultant firm? Is it based on any specific theory? Is it internally developed?

Informant	Sampling
Mgr	
Imp	
ImpAss	Many
Cons	Many
PM participating in the implementation process	Many
FMgr participating in the implementation process	Many
Specialists participating in the implementation process	Repr

Document	Sampling
ImPlan	
FeaS	
CostD	
PerfM(lead-times after and before; cost on developments after and before; rework, and so on.)	
Papers	
Public	

C.3 Questions on the operation

✓How do you develop new products? (what is the process?) (sparkling question)

✓What is your role/activities in the development of new products?

✓How do you work with CE/PM?

✓ How do you assign and control the resources?

✓What are the main tools/approaches/techniques/software to develop new products?

✓What are the main PM/CE tools and techniques?

✓Who has the overall responsibility for the development of a new product? (position in the plant)

✓Whether the product to develop is very new or innovative or is only an upgrade or modified version, does your process to develop vary considerably? How? How do you measure newness?

✓What are the main problems in operating PM/CE/NPD?

✓What are the main benefits in operating PM/CE/NPD?

✓ What are the performance measurements?

Informant	Sampling
PM	Many
FMgr	
Sp	AL1
Spo	
Pr Mgr	
Mgr	
PmAss	Many
PrAnal	
Cons	

Document	Sampling
Meth	
OCh	As Req
JobD	As Req
PrPlan	At leas two
PerfM of specific projects	At least two

C.4 Questions on improvements, absence and relationships

✓How do you plan for improvements on your current NPD/CE/PM practice?

✓Who is responsible for the improvement?

G Have you implemented other initiatives or programs to improve the development of new products? What? Why?

✓Why have you not implemented a PM/NPD/CE practice or methodology?

✓According to you understanding, what is PM/NPD/CE? How it works?

✓Are you concerned by the absence of this initiative?

✓How do you complement or align the two (three) initiatives to be sure that together they add value or create synergy? What benefits what? What is within what? What is the best order?

✓What is the best approach to develop NPD?

✓ Can you develop NP efficiently with a PM/CE/NPD methodology alone?

✓Are you concerned by how to complement them?

What is the difference (if any) of the roles/position of the project manager, the product manager and the process manager?

What is the difference (if any) between project and process?

And between project management and process management?

Is NPD a process, project or both?

Informant	**Sampling**
Mgr	
PrMgr	
PM	Many
PrAnal	Many
Cons	

Document	**Sampling**
Strategic plans	As req
FeaS	
Papers	
JobD Project management, product management	
Meth	
Lessons learned minutes or reports	Many
JobD or responsible for improvements	As req

Assesments or audit reports	
Min, Mem rejecting new initiatives	
Offers rejected	
Informant	**Sampling**
Mgr	
PrMgr	
PM	**Many**
Spo	

Document	**Sampling**
Meth	
Books	
Papers	

Section D. Guide for the case study report

D.1 Individual case study

The next suggested report outline is taken from the thesis outline

1. Description of the company

2. New Product Development

3. Project Management

4. Concurrent Engineering

5. The interfaces

6. New Product Development performance

D.2 Cross-case analysis

1. The companies

2. New Product Development Methodologies

3. Project Management Approaches

4. Concurrent Engineering Approaches

5. The interfaces

6. New product Development Performance

Appendix D. Analysing Data Aided by QSR N6™ and MindManager™

Coding text

Figure A1 shows an example of how text was coded. The "Document Explorer" window shows the list of documents and interviews. Every document from this list was analysed using the "Browsing Document" window. The figure shows an interview transcript where the answer of the respondent is taken as the unit of analysis (a paragraph). The concept in this unit of analysis is coded into a concept called "Concurrent Engineering". This coded concept is clustered in a tree type structure which is displayed while coding ("Node Explorer" Window).

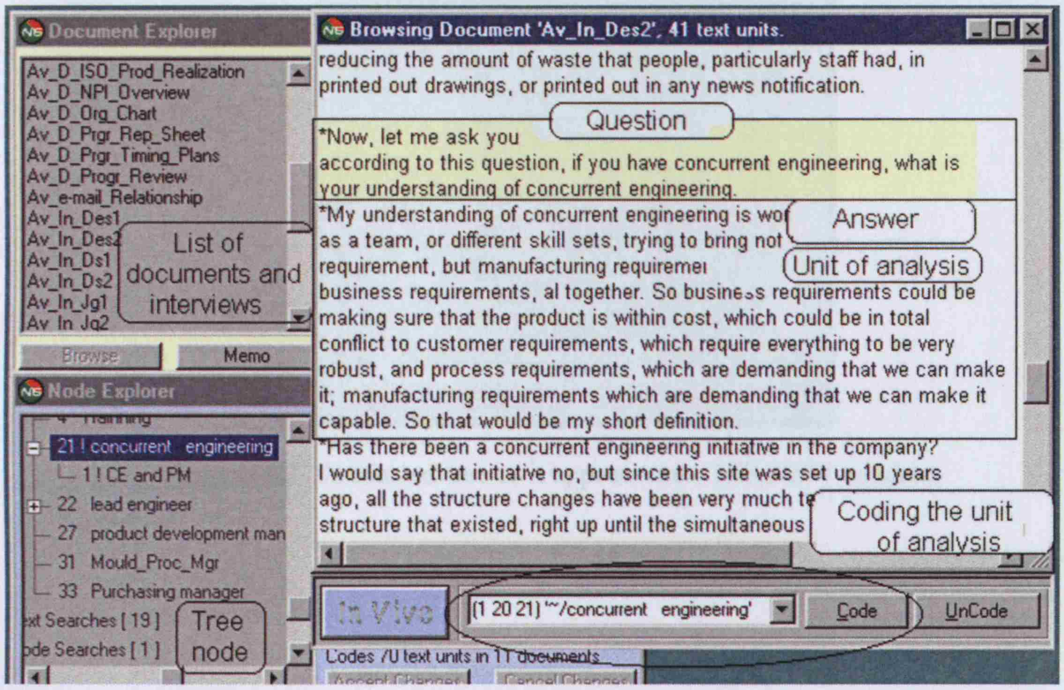


Figure A1. Coding text with the QSR N6™ software

Tree-type structure of conceptual codes

Figure A2 shows the structured tree of conceptual nodes on a "Node Explorer" window. The window shows only the beginning of a 46-node tree. Notice that in this case seven concepts could not be clustered and they appear as "Free Nodes"

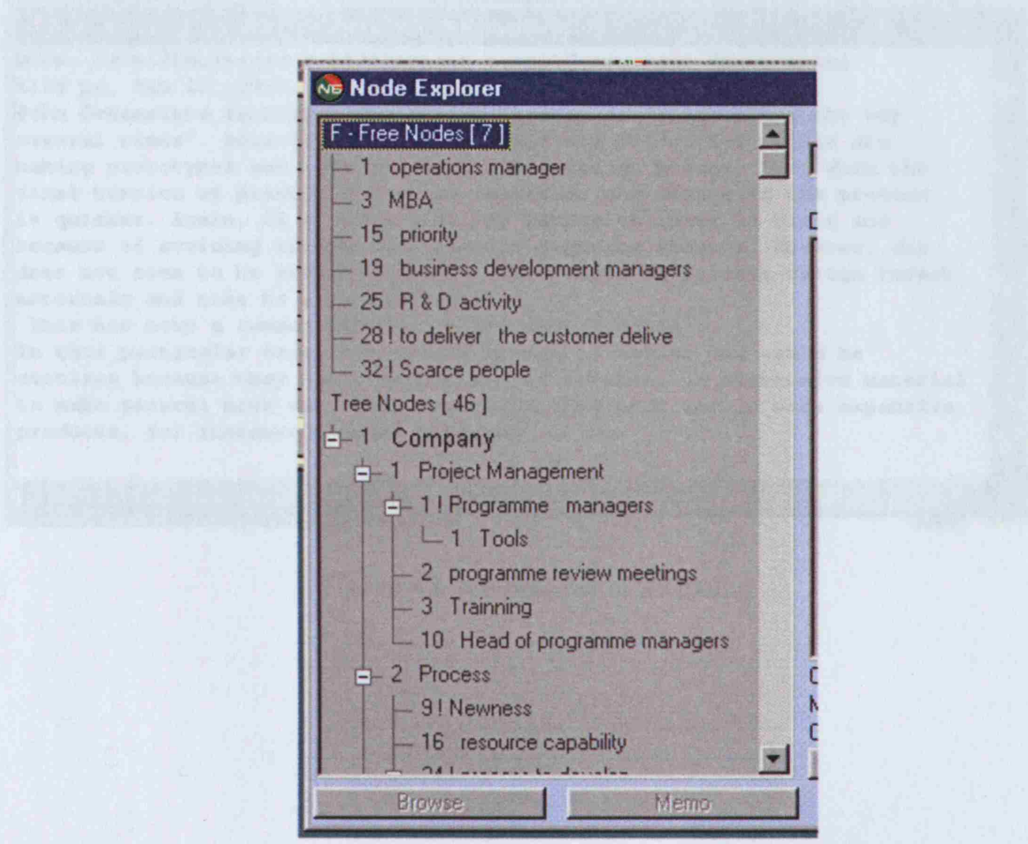


Figure A2. Structured tree as it appears on a QSR N6™ window

Memoing

Figure A3 illustrate an example of the memos developed during the field research. It should be noted that it is written by the researcher to the researcher, therefore, the writing style is (and should be) “agile”, not refined.

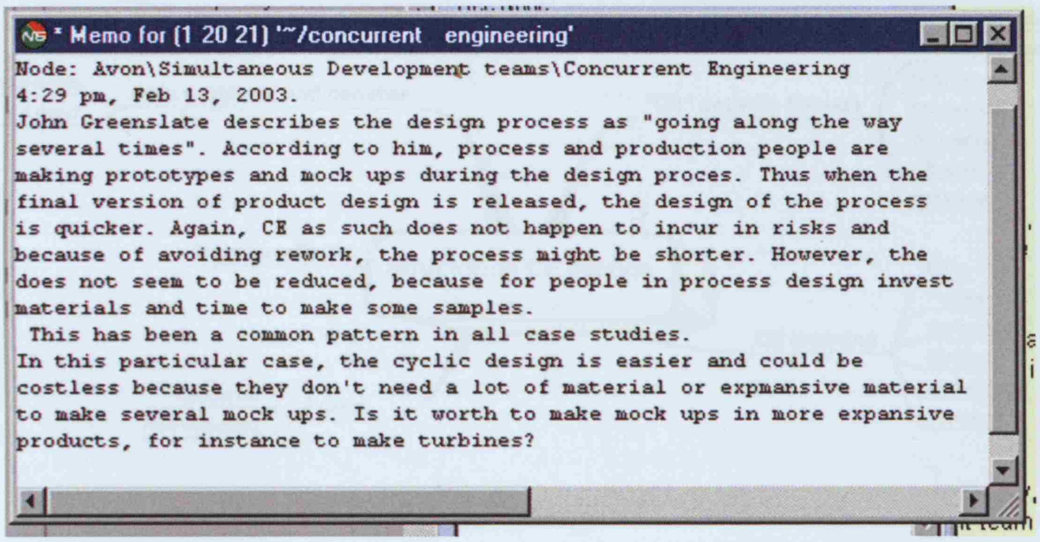


Figure A3. An example of memoing

Relating concepts

Figure A4 portrays an example of how the most important concepts developed during the analysis were related each other. The visual aid helped to structure and elaborate a more consistent and clearer sections of the thesis explaining these concepts

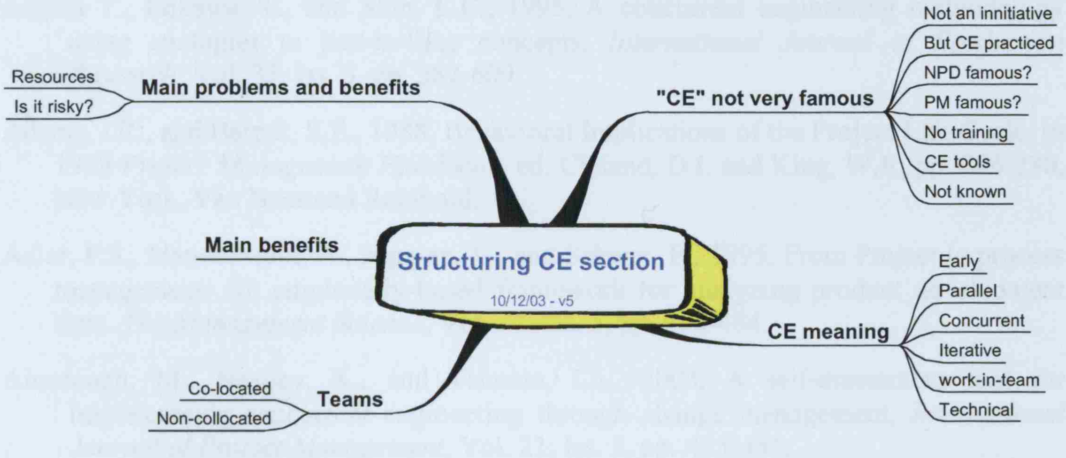


Figure A4 Relating concepts aided by Mindmanager™

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